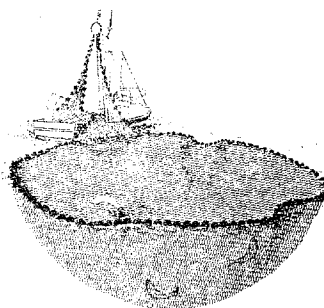
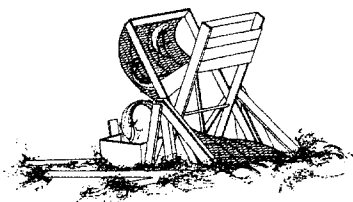
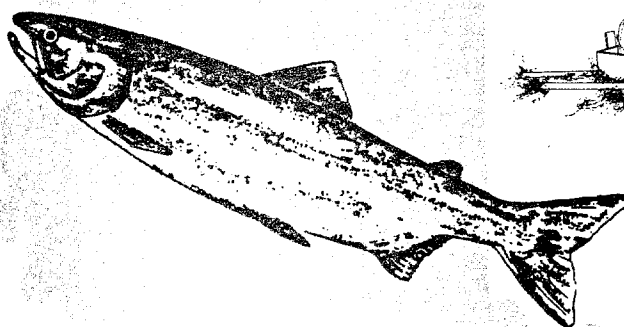
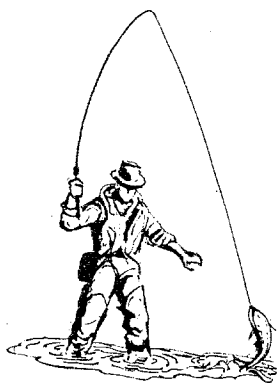
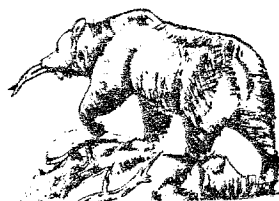


FISH POPULATION CHARACTERISTICS OF ARCTIC NATIONAL WILDLIFE REFUGE COASTAL WATERS, SUMMER 1990

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Fish Population Characteristics of
Arctic National Wildlife Refuge Coastal Waters,
Summer 1990

Alaska Fisheries Progress Report

Tevis J. Underwood, Judith A. Gordon,
and Bruce M. Osborne

Key Words: Fish, distribution, relative abundance, age, condition factor,
movements, Beaufort Sea, Arctic National Wildlife Refuge, Arctic char,
Arctic cisco

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ABSTRACT

In 1990 fishes in the coastal waters of the Arctic National Wildlife Refuge, Alaska were sampled with gill nets and two types of fyke nets from mid-July to mid-September to determine relative abundances, distribution, growth, and movement patterns of anadromous and marine fish species. Standard fyke nets were used in areas protected by barrier islands whereas smaller more mobile nets were fished on the unprotected coast. Specific sampling areas included Camden Bay, Kaktovik and Jago lagoons, and Beaufort Lagoon. Concurrent physical habitat measurements were collected including water temperature, depth and salinity. Ocean current and wind directions and velocities were monitored at Camden Bay and Beaufort Lagoon.

Twenty-three species of fish were identified, enumerated and measured during 1990. We collected 294,887 fish in standard fyke nets. Catch of the five target species included 3,369 Arctic char *Salvelinus alpinus*, 117,316 Arctic cisco *Coregonus autumnalis*, 84,058 Arctic cod *Boreogadus saida*, 41,513 fourhorn sculpin *Myoxocephalus quadricornis* and 25,472 Arctic flounder *Liopsetta glacialis*. The six most abundant species captured in standard fyke nets, in descending order, were Arctic cisco (fork length ≤ 200 mm), Arctic cod, fourhorn sculpin, Arctic flounder, capelin *Mallotus villosus* and ninespine stickleback *Pungitius pungitius*. Relative abundance, as measured by seasonal catch rates, varied by sampling area and stations for these species. Daily catch rates by station also varied widely. The experimental, smaller more mobile nets, turned out to be ineffective because the hostile environment did not allow them to be fished.

Gill net sampling conducted in Camden Bay to examine offshore distribution resulted in the capture of 181 Arctic char and 25 Arctic cisco. Catches varied widely among stations located at the 2.4, 4.9 and 7.3 m depth contours and were inconclusive. In addition weather conditions kept sample sizes low making comparisons tenuous.

Otoliths were collected from 443 Arctic cisco. Mean lengths at age for fish collected in July were 58, 120, 156 and 226 mm for ages 0-3, respectively. Instantaneous growth rates in weight ranged from -0.28 to 1.0 over the 50-day sampling season.

Weight and length data for Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin and Arctic flounder were analyzed using geometric mean regression (weight-length relationship), length frequency distributions and analysis of fish condition. Analysis of covariance detected significant differences in fish condition ($P < 0.05$) between early season and late season for all target species except Arctic char.

Crews dye marked Arctic char (N=1,186) and Arctic cisco (N=1,965) less than 300 mm FL. One dye marked Arctic cisco moved westward from Kaktovik Lagoon to Camden Bay. All other recaptured fish (40 Arctic char and 2 Arctic cisco) fish were recaptured in the sampling area where dye marking occurred.

We tagged Arctic char (N=964) and Arctic cisco (N=497) greater than or equal

to 300 mm FL and Arctic flounder (N=655) and fourhorn sculpin (N=465) greater than 200 mm TL with Floy® anchor tags. Thirteen Arctic char, 11 Arctic cisco, 4 least cisco, 11 fourhorn sculpin and 17 Arctic flounder were recaptured. All Arctic cisco and least cisco *Coregonus sardinella* recaptures were originally tagged in the Prudhoe Bay area. Travel distance for recaptured fish ranged from 0 to 202 km. Fish that we recaptured did not move between sampling areas except for one Arctic char (Jago Lagoon to Camden Bay) and one fourhorn sculpin (Camden Bay to Kaktovik Lagoon). Several Arctic char and Arctic cisco were recaptured by sport or subsistence fishers outside the sampling areas and after the field season in locations as distant as the Colville River and Canada.

TABLE OF CONTENTS

LIST OF TABLES	v
LIST OF FIGURES	vi
INTRODUCTION	1
STUDY AREA	5
METHODS	10
SAMPLING GEAR	10
Standard Fyke Nets	10
Gill Nets	10
Experimental Fyke Nets	14
RELATIVE ABUNDANCE AND DISTRIBUTION	14
Sample Processing	14
Catch Data Analyses	16
LENGTH FREQUENCY DISTRIBUTIONS	16
WEIGHT-LENGTH RELATIONSHIPS	17
Data Collection	17
Data Analysis	17
FISH CONDITION	17
INSTANTANEOUS GROWTH	18
FISH MOVEMENTS	18
HYDROGRAPHIC AND METEOROLOGIC SAMPLING	19
RESULTS	20
RELATIVE ABUNDANCE AND DISTRIBUTION	20
Standard Fyke Nets	20
Gill Nets	37
Experimental Fyke Nets	37
LENGTH FREQUENCY DISTRIBUTIONS	47
Standard Fyke Nets	47
Gill Nets	68
WEIGHT-LENGTH RELATIONSHIPS	68
FISH CONDITION	68
INSTANTANEOUS GROWTH	68
FISH MOVEMENTS	68
DISCUSSION	85
RELATIVE ABUNDANCE AND DISTRIBUTION	85
LENGTH FREQUENCY DISTRIBUTIONS	87
WEIGHT-LENGTH RELATIONSHIPS	88
FISH CONDITION	88
FISH MOVEMENTS	88
ACKNOWLEDGMENTS	90
REFERENCES	91
APPENDIX A: Length Frequency Distributions of Arctic char and Arctic cod in 5 mm increments.	94

LIST OF TABLES

Table	Page
1. Sampling station locations, types of data obtained and inclusive dates of sampling, July through September 1990.	11
2. Fish species captured in Arctic Refuge coastal waters during July-September 1990.	21
3. Total standard fyke net catch by sampling station in Arctic Refuge coastal waters, July-September 1990.	22
4. Seasonal catch per unit effort (fish/d) by standard fyke net sampling stations in Arctic Refuge coastal waters, July - September 1990. . .	23
5. Total catch of Arctic Char and Arctic cisco by gill net sampling stations in Arctic Refuge coastal waters, July - September 1990. . .	44
6. Mean (\pm SD) catch per hour (CPUE), CPUE range, and number of observations (N) by depth interval for Arctic char caught in gill net sampling in Camden Bay, Alaska, July - September 1990.	45
7. Mean (\pm SD) catch per hour (CPUE), CPUE range, and number of observations (N) by depth interval for Arctic cisco caught in gill net sampling in Camden Bay, Alaska, July - September 1990.	46
8. Total experimental fyke net catch by sampling stations in Arctic Refuge coastal waters, July-September 1990.	48
9. Seasonal catch per unit effort (fish/d) by experimental fyke net sampling stations in Arctic Refuge coastal waters, July - September 1990.	49
10. Mean fork length at age of Arctic cisco captured during the early (July 10-24) and late (August 29-September 14) periods from Arctic Refuge coastal waters 1990.	77
11. Instantaneous growth rates (G) of Arctic cisco, ages 0-4.	78
12. Number of fish dye-marked (N) and recaptured, by location, during the summer of 1990, Arctic Refuge coastal waters.	79
13. Number of fish Floy tagged (N) and recaptured, by location, during the summer of 1990, Arctic Refuge coastal waters.	81
14. Summary of tagging and recapture data for fish species recaptured in Arctic Refuge coastal waters, summer, 1990.	82

LIST OF FIGURES

<i>Figure</i>	<i>Page</i>
1. Eastern Beaufort Sea coast, coastal plain of the Arctic Refuge, and areas sampled for fish and physical hydrographic characteristics during July through September, 1990.	2
2. Sampling stations in the Camden Bay study area on the Arctic Refuge during July through September, 1990.	6
3. Sampling stations in the Kaktovik and Jago lagoons study area on the Arctic Refuge during July through September, 1990.	7
4. Sampling stations in the Beaufort Lagoon study area on the Arctic Refuge during July through September, 1990.	8
5. Standard and experimental fyke net configuration.	13
6. Gill net configuration used for fishing in 7.3 meters water depth.	15
7. Daily catch per unit effort (fish/d) for Arctic char at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	25
8. Daily catch per unit effort (fish/d) for Arctic char at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	26
9. Daily catch per unit effort (fish/d) for Arctic char at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	27
10. Daily catch per unit effort (fish/d) for small Arctic cisco (≤ 200 mm FL) at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	28
11. Daily catch per unit effort (fish/d) for small Arctic cisco (≤ 200 mm FL) at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	29
12. Daily catch per unit effort (fish/d) for small Arctic cisco (≤ 200 mm FL) at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	30
13. Daily catch per unit effort (fish/d) for large Arctic cisco (> 200 mm FL) at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	31

14. Daily catch per unit effort (fish/d) for large Arctic cisco (>200 mm FL) at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	32
15. Daily catch per unit effort (fish/d) for large Arctic cisco (>200 mm FL) at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	33
16. Daily catch per unit effort (fish/d) for Arctic cod at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	34
17. Daily catch per unit effort (fish/d) for Arctic cod at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	35
18. Daily catch per unit effort (fish/d) for Arctic cod at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	36
19. Daily catch per unit effort (fish/d) for fourhorn sculpin at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	38
20. Daily catch per unit effort (fish/d) for fourhorn sculpin at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	39
21. Daily catch per unit effort (fish/d) for fourhorn sculpin at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	40
22. Daily catch per unit effort (fish/d) for Arctic flounder at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	41
23. Daily catch per unit effort (fish/d) for Arctic flounder at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	42
24. Daily catch per unit effort (fish/d) for Arctic flounder at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	43
25. Length frequency of Arctic char captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	50
26. Length frequency of Arctic char captured by fyke nets in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	51

27. Length frequency of Arctic char captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	52
28. Length frequency of small Arctic cisco (<300 mm FL) captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	53
29. Length frequency of small Arctic cisco (<300 mm FL) captured by fyke nets in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	54
30. Length frequency of small Arctic cisco (<300 mm FL) captured in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	55
31. Length frequency of large Arctic cisco (\geq 300 mm FL) captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	56
32. Length frequency of large Arctic cisco (\geq 300 mm FL) captured by fyke nets in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	57
33. Length frequency of large Arctic cisco (\geq 300 mm FL) captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	58
34. Length frequency of Arctic cod captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	59
35. Length frequency of Arctic cod captured by fyke nets in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	60
36. Length frequency of Arctic cod captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	61
37. Length frequency of fourhorn sculpin captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	62
38. Length frequency of fourhorn sculpin captured by fyke nets in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	63
39. Length frequency of fourhorn sculpin captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	64
40. Length frequency of Arctic flounder captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	65
41. Length frequency of Arctic flounder captured by fyke nets in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.	66

42. Length frequency of Arctic flounder captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.	67
43. Length frequency of Arctic char and Arctic cisco captured by gill nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.	69
44. Weight-length relationships of Arctic char captured by fyke nets in Arctic Refuge coastal waters.	70
45. Weight-length relationships of Arctic cisco captured by fyke nets in Arctic Refuge coastal waters.	71
46. Weight-length relationships of Arctic cod captured by fyke nets in Arctic Refuge coastal waters.	72
47. Weight-length relationships of fourhorn sculpin captured by fyke nets in Arctic Refuge coastal waters.	73
48. Weight-length relationships of Arctic flounder captured by fyke nets in Arctic Refuge coastal waters.	74
49. Fish condition as modeled by weight-length relationship for Arctic char, Arctic cisco and Arctic cod.	75
50. Fish condition as modeled by weight-length relationship for fourhorn sculpin and Arctic flounder.	76

INTRODUCTION

Increasing attention has focused on the possibility of commercial quantities of oil and gas lying beneath the coastal plain (Figure 1) of the Arctic National Wildlife Refuge (Arctic Refuge) since discovery of the Prudhoe Bay oil field in 1968. A report to the U.S. Congress (Clough et al. 1987) indicated a 19% chance of finding recoverable oil and gas and described a scenario of how those resources might be produced from the area and transported to refining facilities. Oil and gas leasing on the refuge is currently prohibited by Section 1003 of the Alaska National Interest Lands Conservation Act. If legislation is passed in the future which allows exploration and eventual production of oil and gas on the coastal plain, development of coastal support facilities such as ports will likely occur.

In addition to possible oil production on the coastal plain, a number of oil leases have been sold in federal and state waters offshore of the refuge since the early 1980's. Five exploratory wells have been drilled off the Arctic Refuge coast. Continued exploration in the offshore waters is likely, with possible development of production facilities.

Anadromous and marine fish species utilize lagoons and other nearshore brackish habitat of the coastal Beaufort Sea for feeding during summer (Craig 1984; Fruge et al. 1989; Palmer and Dugan 1990). These areas are important because they are relatively warmer than offshore Beaufort Sea waters and have a high food organism concentration. Such conditions facilitate the accumulation of fat reserves in fish for overwintering and reproduction. The nearshore brackish band also appears to serve as an important migratory pathway for several anadromous species (Craig 1984; Fruge et al. 1989; Palmer and Dugan 1990) particularly Arctic cisco and Arctic char. The physical habitat factors that appear to be most important to fishes in these nearshore waters are salinity and temperature. These habitat factors are in turn determined by nearshore ocean currents which appear to be wind driven (Sharma 1979).

Oil or gas activities and port site development, including causeways and seawater intakes, may affect fish that utilize Beaufort Sea coastal waters. A series of such causeways and/or water intakes may reduce habitat quality for some fish species utilizing coastal areas (Craig 1984). Fish may also be affected by inadvertent oil and other hazardous material spills.

Reliable baseline data are necessary for detecting and mitigating possible effects of oil and gas development on fish populations and habitat. Such data are also necessary to understand fish population dynamics and habitat requirements in Beaufort Sea coastal waters. An understanding of these features is essential to manage and mitigate oil and gas activities.

Fish studies in coastal waters of the refuge began in the summer of 1970 with a gill net study that spanned the entire refuge coastal area (Roguski and Komarek 1971). Refuge coastal waters, including Kaktovik Lagoon, were also sampled in the 1970's by Ward and Craig (1974) and Griffiths et al. (1977) to

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

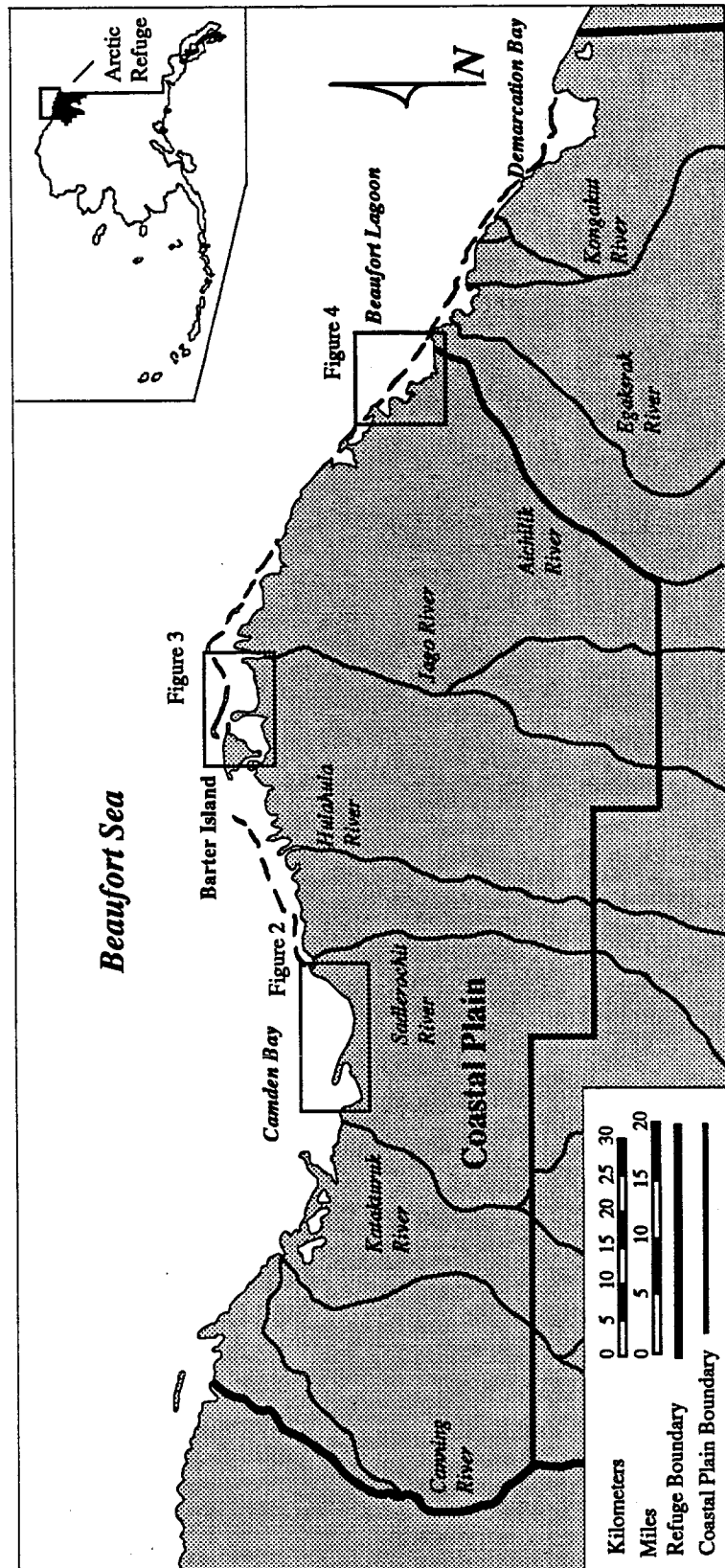


FIGURE 1.- Eastern Beaufort Sea coast, coastal plain of the Arctic Refuge, and areas sampled for fish and physical hydrographic characteristics during July through September, 1990.

gather baseline data for a proposed gas pipeline across the refuge. Beaufort and Angun lagoons were studied in 1982 by Griffiths (1983) as part of a biological characterization of eastern Beaufort Sea lagoons. Craig (1983) sampled Kaktovik Lagoon during the summer of 1983 to monitor effects of gravel dredging on the east shore of Barter Island. Kaktovik Lagoon was also sampled by fyke nets in 1985 as part of a study of the Kaktovik subsistence fishery (Nelson et al. 1986). The U.S. Fish and Wildlife Service began sampling refuge coastal waters with a fyke net survey of Beaufort Lagoon during the summers of 1984 and 1985 (West and Wiswar 1985; Wiswar and West 1987). This work continued with similar surveys of Oruktalik Lagoon in 1986 (Wiswar et al. in preparation) and western Camden Bay in 1987 (Wiswar and Fruge in preparation).

Although the above studies resulted in a substantial amount of fisheries data from refuge coastal waters, none of these studies provided site-specific data on fish usage of the areas identified as possible port sites by Clough et al. (1987), nor did any of these studies address annual variability in fish distribution, abundance, growth and movement. Information on fish distribution and abundance and related hydrographic characteristics is needed to assess potential impacts on fish populations. For a complete picture, fisheries and hydrographic data would need to be collected over a several-year period in areas of potential development. Such information could also be utilized in designing and siting coastal structures and activities so that critical fish habitats and migration corridors would be protected.

To improve the existing baseline data on coastal fish populations and habitats, the U.S. Fish and Wildlife Service began a 5-year study in 1988. Sampling efforts during 1988 focused on three study areas (Frue et al. 1989). Two of these areas, Camden Bay and the bluff area west of Pokok Bay, are potential port sites. A third study area was comprised of Kaktovik and Jago lagoons, near Barter Island. The Pokok "bluff" study area was abandoned in 1989 due to heavy concentrations of pack ice close to shore for most of the summer in 1988. Beaufort Lagoon, approximately 19 km east of the Pokok area, replaced the Pokok area as a study area in 1989. Beaufort Lagoon was selected as a study area because some baseline data were collected at this location in 1984-85 (West and Wiswar 1985; Wiswar and West 1987). This area is also protected by barrier islands and can be sampled regardless of pack ice conditions. In 1990, Camden Bay, Kaktovik and Jago lagoons and Beaufort Lagoon were again selected as study areas.

We attempted to look at the fish community in the sampling areas as a unit using a relative abundance indicator, catch per unit effort (CPUE). Five "target species" were identified for closer study (e.g. weight-length). The five species included Arctic char *Salvelinus alpinus*, Arctic cisco *Coregonus autumnalis*, Arctic cod *Boreogadus saida*, fourhorn sculpin *Myoxocephalus quadricornis* and Arctic flounder *Liopsetta glacialis*. Previous studies indicated these species were appropriate for additional study (West and Wiswar 1985; Wiswar and West 1987; Frue et al. 1989). The fish selected represent anadromous and marine species; are present at all sampling areas; are generally the most abundant species; are readily sampled by fyke and gill nets; and/or are important for subsistence, sport or commercial fishing.

Specific objectives for the five year study are as follows:

1. Determine relative abundance, distribution, and movement patterns for anadromous and marine fish species;
2. Determine length frequency, age structure, weight-length relationships, and fish condition for Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin and Arctic flounder in Arctic Refuge coastal waters;
3. Characterize the study areas in terms of water temperature and salinity;
4. Determine current patterns offshore from the Camden Bay and Beaufort Lagoon study areas;
5. Determine the relationships of salinity, temperature and current patterns to wind direction and velocity at the study areas;
6. Test the hypotheses that relationships exist between fish distribution and abundance and hydrographic characteristics; and determine the nature of these relationships.

This report summarizes fisheries data from 1990 sampling activities (objectives 1 and 2). The description of the age structure mentioned in objective 2 was addressed by Fruge et al. (1989) and Palmer and Dugan (1990) and is not discussed further in this report. Our report also briefly describes methodology used to collect hydrographic data for objectives 3-5. Data were collected by our personnel and portions of it will be used to address objective 6 in the final project report. A detailed description of hydrographic data collection methodology, analysis and results (objectives 3-5) will be reported by the Ocean Assessments Division of the National Oceanic and Atmospheric Administration (NOAA) who have produced similar reports for the 1988 and 1989 study data (Hale 1990, 1991). Finally, objective 6 will be addressed in the study's final report when all catch and habitat data can be analyzed together.

STUDY AREA

Three areas of the Arctic Refuge coast were sampled for fish and hydrographic characteristics: Camden Bay, Kaktovik and Jago lagoons, and Beaufort Lagoon (Figures 2-4). The western most sampling area, Camden Bay (Figure 2), is centered approximately 43 km southwest of the village of Kaktovik. Camden Bay is a broad open-water zone along the Arctic Refuge coast extending between the Canning River delta (Figure 1) and Anderson Point (Figure 2). Collinson Point, a gravel/sand spit extending into Camden Bay, partially encloses an embayment known as Simpson Cove where maximum depth is approximately 3.4 m (Nautical Chart 16044, U.S. Department of Commerce). Most of the Camden Bay shoreline is sand/gravel beach at the base of tundra bluffs 1-2 m high, although in some areas these bluffs may be as high as 3-5 m.

Camden Bay, east of Collinson Point, consists of a broad bight extending southeastward and then curving northeastward toward Anderson Point. This bight area was identified by Clough et al. (1987) as a possible port site should oil and gas development occur. Depth in this part of Camden Bay drops off quickly, reaching depths of around 6 m within about 0.5 km of the shore (Nautical Chart 16044, U.S. Department of Commerce). The bottom gradient is less offshore, reaching a depth of about 9 m approximately 5 km from shore (Nautical Chart 16044, U.S. Department of Commerce).

The major stream drainages discharging into Camden Bay are the Katakturuk River and Marsh and Carter creeks. Several unnamed smaller streams also drain into the bay. Other major rivers nearby include the Canning River to the west and the Sadlerochit and Hulahula rivers to the east.

Kaktovik and Jago lagoons are located immediately east of Barter Island (Figure 3). Barter Island forms the western and northern shores of Kaktovik Lagoon. Jago Lagoon is east of Kaktovik Lagoon separated by a low sand/gravel spit between the mainland and Manning Point. The spit is sometimes inundated during periods of high water making the two lagoons contiguous. Jago Lagoon is separated from the Beaufort Sea by a barrier island. The Jago River delta forms the eastern shore of Jago Lagoon.

Kaktovik Lagoon is a pulsing lagoon, where water exchange is facilitated by changes in water level due to tide and wind (Hachmeister and Vinelli 1984). It has two channels leading to other waters. The primary channel, known as Nelsaluk Pass, connects Kaktovik and Jago lagoons. Another shallow channel at the southwest end of Kaktovik Lagoon opens to waters west of Barter Island. No large streams empty into Kaktovik Lagoon.

Jago Lagoon is a limited exchange lagoon (Hachmeister and Vinelli 1984) having only limited alongshore marine water exchange via two openings in the barrier island system to the Beaufort Sea. One is in the western part of the lagoon between Barter Island and Bernard Spit. The other, known as Jago Entrance, is a much broader opening to the Beaufort Sea near the Jago River delta between Bernard Spit and Jago Spit. Jago Lagoon is also connected to another lagoon to the east by a shallow expanse of water between the Jago River delta and Jago Spit. Other than the Jago River, there are no prominent

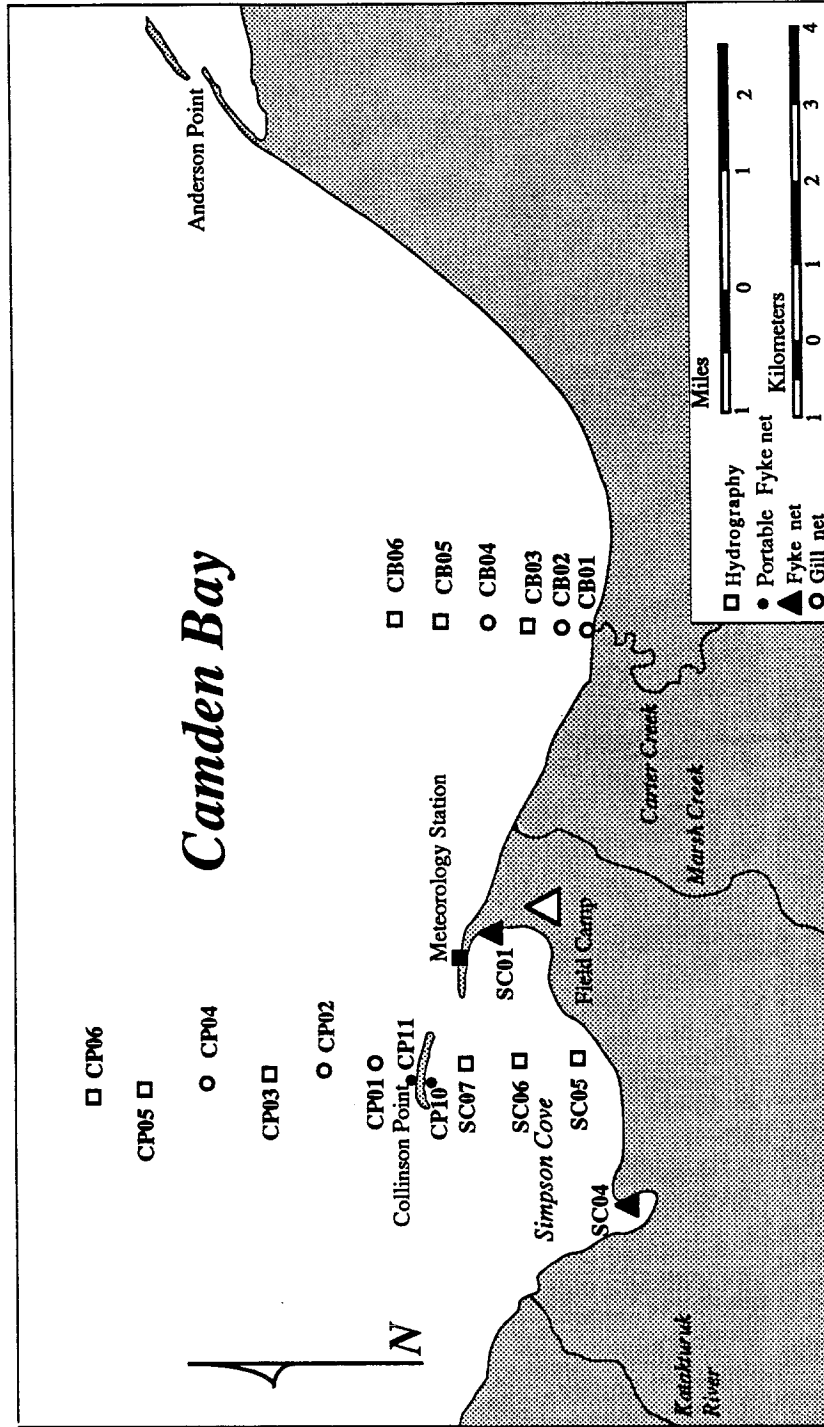


FIGURE 2.— Sampling stations in the Camden Bay study area on the Arctic Refuge during July through September, 1990.

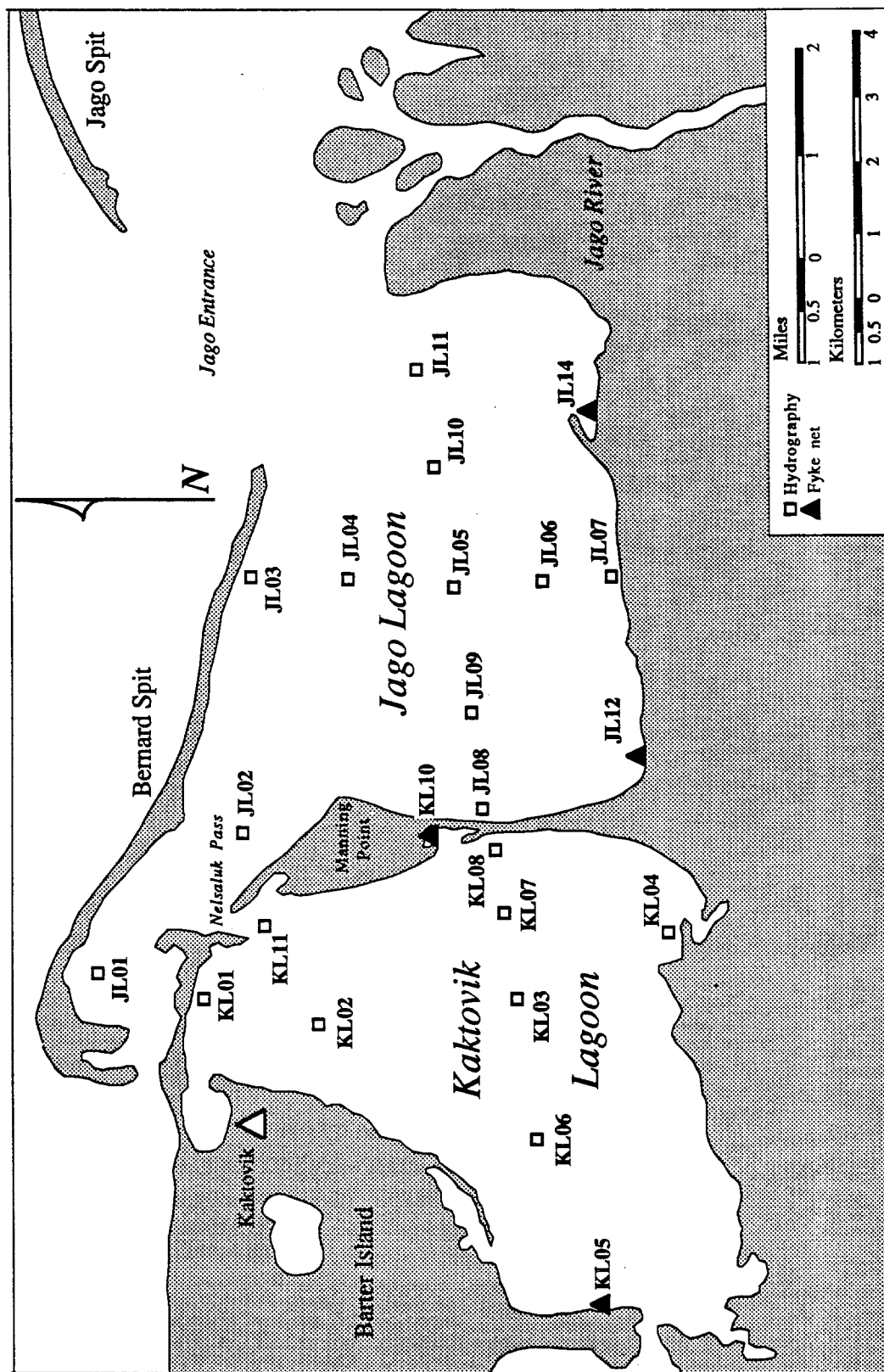


FIGURE 3.— Sampling stations in the Kaktovik and Jago lagoons study area on the Arctic Refuge during July through September, 1990.

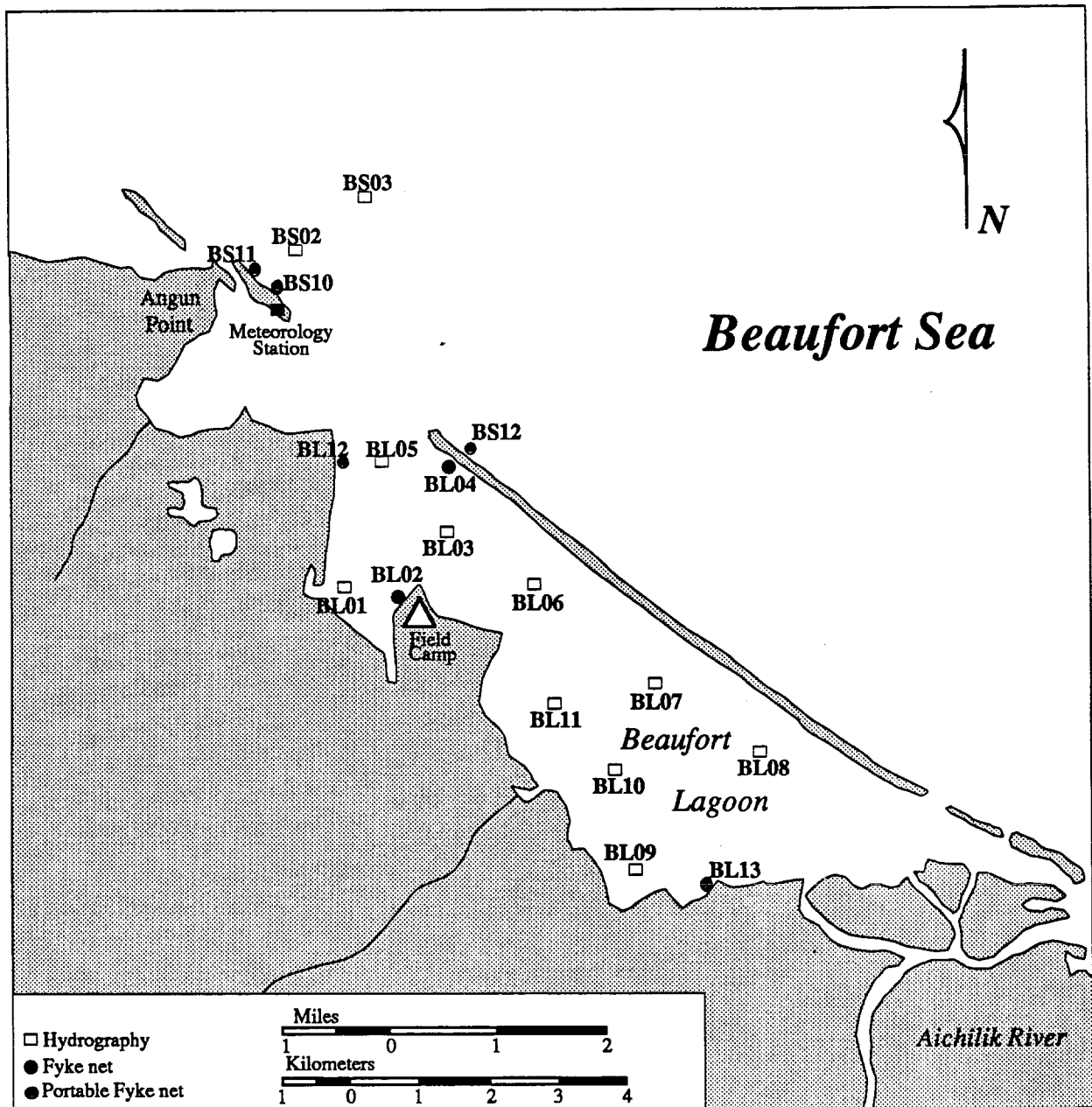


FIGURE 4.— Sampling stations in the Beaufort Lagoon study area on the Arctic Refuge during July through September, 1990.

streams draining into Jago Lagoon.

Maximum water depth in Kaktovik and Jago lagoons is approximately 4 m (Nautical Chart 16043, U.S. Department of Commerce). Most of the shoreline of these two lagoons consists of sand/gravel beach below tundra bluffs. The southwestern shore of Kaktovik Lagoon along the southeastern part of Barter Island has less beach area and the bluffs are lower in elevation than most of the rest of the shoreline.

The Beaufort Lagoon study area (Figure 4) is centered approximately 55 km southeast of Kaktovik and extends from Angun Point eastward to the Aichilik River delta. This study area comprises the western portion of Beaufort Lagoon which is actually a series of small interconnected narrow lagoons extending eastward to Demarcation Bay (Figure 1). Hachmeister and Vinelli (1984) described Beaufort Lagoon as a limited exchange lagoon. Maximum water depth in Beaufort Lagoon is approximately 4 m (Nautical Chart 16042, U.S. Department of Commerce). The shoreline is also primarily sand/gravel beaches below tundra bluffs.

Additional information on the physical characteristics of Camden Bay, Kaktovik and Jago lagoons and Beaufort Lagoon are given by Hale (1990, 1991).

METHODS

SAMPLING GEAR

Standard Fyke Nets

As in previous years, fish were captured using standard fyke nets in lagoons and protected nearshore areas in water depths of 1.3 m or less (Figures 2-4 and Table 1). Standard fyke nets were fished in Camden Bay, Kaktovik, Jago and Beaufort lagoons from approximately July through September. Standard fyke nets were checked once daily unless severe weather did not allow safe boat travel.

In Camden Bay, two fyke net stations (SC01 and SC04) were established in 1988 in the semi-protected waters of Simpson Cove. These stations were selected because they had been successfully fished in 1987 and it was thought that additional data could be added to that baseline (Wiswar, U.S. Fish and Wildlife Service, personal communication).

Fyke net stations in Kaktovik Lagoon (net stations KL05 and KL10) and Jago Lagoon (stations JL12 and JL14) were originally selected because of their proximity to potential pathways for fish entering and exiting the lagoons. Two stations, KL10 in Nelsaluk Pass and JL14 on the Northeast side of Manning Point, were relocated after floating ice proved problematic in the first weeks of 1988. Their new locations were in more protected coves making them less vulnerable to ice but farther from the expected fish pathways (Wiswar, U.S. Fish and Wildlife Service, personal communication).

Two net stations were selected in Beaufort Lagoon. Stations BL02 and BL04 were identical to those of previous studies (West and Wiswar 1985; Wiswar and West 1987).

Standard fyke nets consisted of two adjacent traps each constructed with 1.5-m wide and 1.2-m high frames at the mouth. The mesh sizes were 12.5-mm stretch for the traps and 25-mm stretch for the wings and leads. A 61-m lead was anchored between the two traps with 15-m wings extending from the frames' outside edges (Figure 5). The lead was set perpendicular to the shoreline with one end anchored to shore. Traps were set offshore in water 1.3 m in depth or less. The fyke net was configured such that fish approaching the net were trapped in the cod end on the side from which they entered. All standard fyke nets were fished with leads fully extended except at Station KL10 where only 30 m of lead was used because of the steep bottom gradient. Traps, lead, and wings were anchored in place using solid steel rods 3 m in length and 1.5 cm in diameter.

Gill Nets

Gill nets were used to sample fish in unprotected, deep, open waters of Camden Bay (Table 1 and Figure 2). The purpose was to examine distribution of Arctic char and Arctic cisco at stations progressively farther from shore. Nets were set perpendicular to the shoreline. Three replicate net sets were made at each gill net station with the replicates set end-to-end rather than side-by-side to reduce gear competition. Gill nets were to be fished every

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

TABLE 1.- Sampling station locations, types of data obtained and inclusive dates of sampling, July through September 1990.

Station	Sampling area	Latitude	Longitude	Fyke net	Gill net	CTD ^a	Current meter	Sampling ^b dates
KL01	Kaktovik Lagoon	70° 07.94' N	143° 34.15' W			X		Jul 14 - Sep 13
KL02	Kaktovik Lagoon	70° 07.12' N	143° 34.63' W			X		Jul 14 - Sep 13
KL03	Kaktovik Lagoon	70° 06.00' N	143° 34.26' W			X		Jul 14 - Sep 13
KL04	Kaktovik Lagoon	70° 05.08' N	143° 32.90' W			X		Jul 14 - Sep 13
KL05	Kaktovik Lagoon	70° 05.44' N	143° 39.56' W	X		X		Jul 9 - Sep 13
KL06	Kaktovik Lagoon	70° 05.83' N	143° 36.65' W			X		Jul 14 - Sep 13
KL07	Kaktovik Lagoon	70° 06.16' N	143° 32.72' W			X		Jul 14 - Sep 13
KL08	Kaktovik Lagoon	70° 06.22' N	143° 31.28' W			X		Jul 14 - Sep 13
KL10	Kaktovik Lagoon	70° 06.59' N	143° 31.00' W	X		X		Jul 9 - Sep 14
KL11	Kaktovik Lagoon	70° 07.60' N	143° 32.62' W			X		Jul 18 - Sep 13
JL01	Jago Lagoon	70° 08.50' N	143° 33.50' W			X		Jul 14 - Sep 13
JL02	Jago Lagoon	70° 07.72' N	143° 31.12' W			X		Jul 14 - Sep 13
JL03	Jago Lagoon	70° 07.70' N	143° 26.40' W			X		Jul 14 - Sep 13
JL04	Jago Lagoon	70° 07.20' N	143° 26.45' W			X		Jul 14 - Sep 13
JL05	Jago Lagoon	70° 06.60' N	143° 26.40' W			X		Jul 14 - Sep 13
JL06	Jago Lagoon	70° 06.00' N	143° 26.49' W			X		Jul 14 - Sep 13
JL07	Jago Lagoon	70° 05.42' N	143° 26.49' W			X		Jul 14 - Sep 13
JL08	Jago Lagoon	70° 06.24' N	143° 30.45' W			X		Jul 14 - Sep 13
JL09	Jago Lagoon	70° 06.41' N	143° 28.45' W			X		Jul 14 - Sep 13
JL10	Jago Lagoon	70° 06.71' N	143° 24.10' W			X		Jul 14 - Sep 13
JL11	Jago Lagoon	70° 06.88' N	143° 22.30' W			X		Jul 14 - Sep 13
JL12	Jago Lagoon	70° 05.22' N	143° 28.50' W	X		X		Jul 10 - Sep 13
JL14	Jago Lagoon	70° 05.51' N	143° 22.23' W	X		X		Jul 10 - Sep 14
SC01	Camden Bay	69° 58.98' N	144° 50.20' W	X		X		Jul 12 - Sep 10
SC04	Camden Bay	69° 57.66' N	144° 57.00' W	X		X		Jul 12 - Sep 14
SC05	Camden Bay	69° 58.00' N	144° 53.12' W			X		Jul 14 - Sep 10
SC06	Camden Bay	69° 58.42' N	144° 54.00' W			X		Jul 14 - Sep 10
SC07	Camden Bay	69° 59.42' N	144° 54.36' W			X		Jul 12 - Sep 5

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

TABLE 1.- Continued.

Station	Sampling area	Latitude	Longitude	Fyke net	Gill net	CTD ^a	Current meter	Sampling ^b dates
CP01	Camden Bay	69° 59.09' N	144° 54.12' W		X	X		Jul 14 - Sep 10
CP02	Camden Bay	69° 59.54' N	144° 54.36' W		X	X		Jul 12 - Sep 5
CP03	Camden Bay	70° 00.02' N	144° 54.36' W			X		Jul 12 - Sep 5
CP04	Camden Bay	70° 00.30' N	144° 54.36' W		X	X		Jul 12 - Sep 5
CP05	Camden Bay	70° 00.48' N	144° 54.36' W			X		Aug 14 - Sep 5
CP06	Camden Bay	70° 01.02' N	144° 54.36' W			X		Aug 14 - Sep 5
CP10	Camden Bay	69° 59.25' N	144° 54.36' W	X		X		Jul 10 - Sep 10 ^c
CP11	Camden Bay	69° 59.22' N	144° 54.36' W	X		X		Jul 10 - Sep 10 ^c
CB01	Camden Bay	69° 58.10' N	144° 42.13' W		X	X		Jul 12 - Sep 9
CB02	Camden Bay	69° 58.17' N	144° 42.13' W		X	X	X	Jul 12 - Sep 9
CB03	Camden Bay	69° 58.50' N	144° 42.13' W			X		Jul 12 - Sep 9
CB04	Camden Bay	69° 58.93' N	144° 42.13' W		X	X		Jul 12 - Sep 9
CB05	Camden Bay	69° 59.32' N	144° 42.13' W			X		Jul 12 - Sep 9
CB06	Camden Bay	69° 59.60' N	144° 42.13' W			X	X	Jul 12 - Sep 9
BL01	Beaufort Lagoon	69° 53.43' N	142° 19.78' W			X		Jul 13 - Sep 10
BL02	Beaufort Lagoon	69° 53.28' N	142° 18.59' W			X		Jul 10 - Sep 14
BL03	Beaufort Lagoon	69° 53.81' N	142° 17.78' W	X		X		Jul 13 - Sep 10
BL04	Beaufort Lagoon	69° 54.35' N	142° 17.23' W	X		X		Jul 11 - Sep 10
BL05	Beaufort Lagoon	69° 54.38' N	142° 18.82' W			X		Jul 13 - Sep 10
BL06	Beaufort Lagoon	69° 53.57' N	142° 15.87' W			X		Jul 13 - Sep 10
BL07	Beaufort Lagoon	69° 52.69' N	142° 13.52' W			X		Jul 13 - Sep 10
BL08	Beaufort Lagoon	69° 52.15' N	142° 10.98' W			X		Jul 13 - Sep 10
BL09	Beaufort Lagoon	69° 51.10' N	142° 13.72' W			X		Jul 13 - Sep 10
BL10	Beaufort Lagoon	69° 52.00' N	142° 13.73' W			X		Jul 13 - Sep 10
BL11	Beaufort Lagoon	69° 52.52' N	142° 15.09' W			X		Jul 13 - Sep 10
BL12	Beaufort Lagoon	54° 25.00' N	142° 20.00' W	X		X		Jul 30 - Sep 13 ^c
BL13	Beaufort Lagoon	51° 00.00' N	142° 14.00' W	X		X		Aug 8 - Sep 13 ^c
BS10	Beaufort Sea	69° 55.35' N	142° 29.35' W	X		X		Jul 18 - Jul 24 ^c
BS11	Beaufort Sea	69° 54.40' N	142° 17.23' W	X		X		Jul 18 - Jul 24 ^c
BS02	Beaufort Sea	69° 55.85' N	142° 21.35' W				X	Jul 26 - Sep 10
BS03	Beaufort Sea	69° 57.25' N	142° 20.42' W				X	Jul 13 - Sep 10

^aCTD = conductivity (salinity), temperature, depth

^bSampling by CTD may not correspond exactly with beginning and ending dates for biological sampling.

^cExperimental fyke net locations were sampled intermittently throughout the sample season.

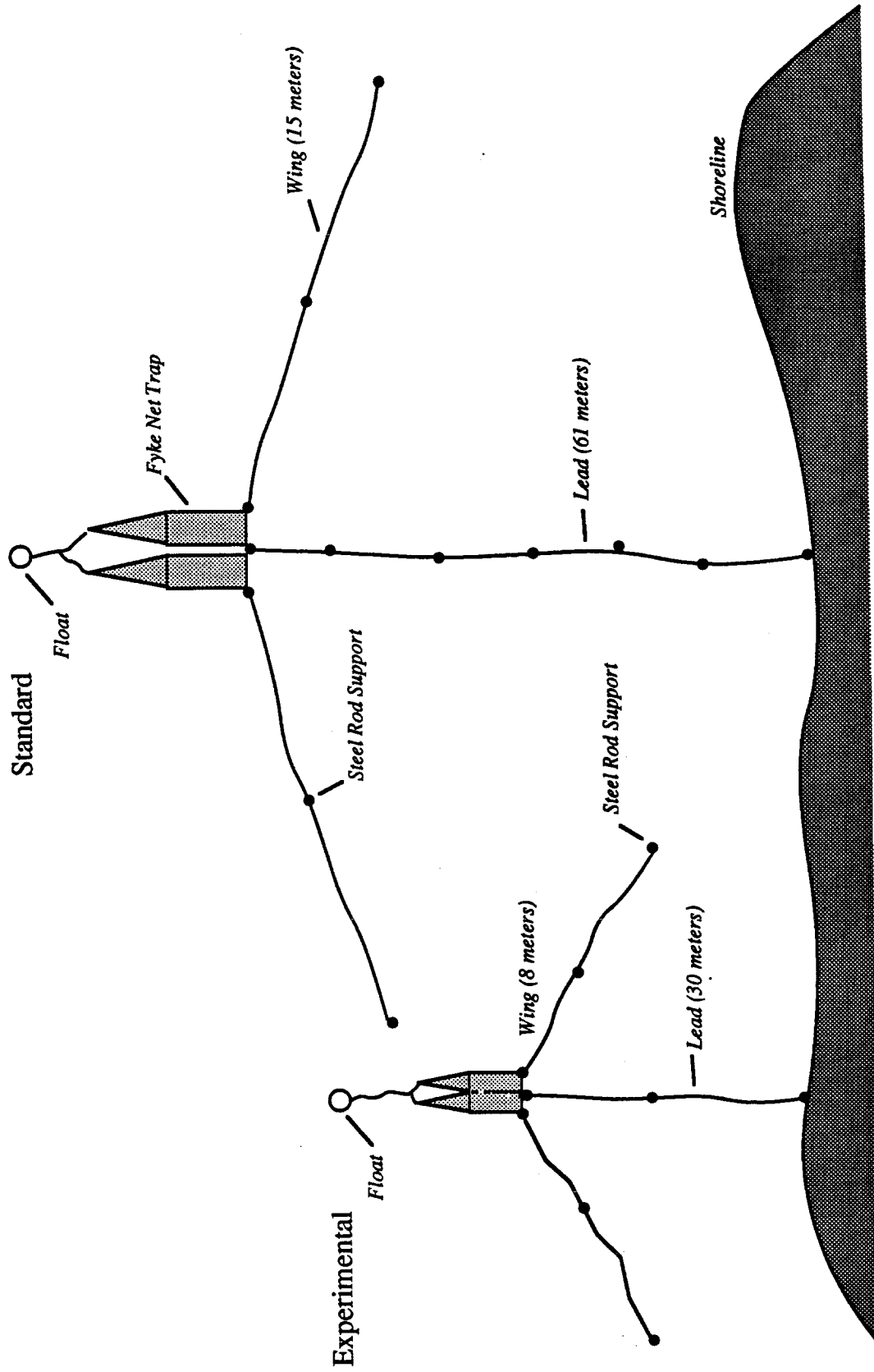


FIGURE 5.— Standard and experimental fyke net configuration.

other day, however, severe weather often interrupted this schedule. The net soak time target was six hours. The depth where each fish was captured (i.e., 0-2.4 m, 2.4-4.9 m, 4.9-7.3 m) as well as direction of travel (east or west) was recorded.

The gill nets consisted of five panels; each panel measured 7.6 m in length and 2.4 m in depth. Each panel was a different mesh size: 19-mm, 25-mm, 38-mm, 51-mm, and 64-mm. Mesh panels were randomly placed within each net during net construction. Gill net sampling stations were located in water depths of 2.4 m (Stations CB01 and CP01), 4.9 m (Stations CB02 and CP02), and 7.3 m (Stations CB04 and CP04). In order to sample the entire water column at the 4.9 and 7.3 m depths, nets were vertically attached to each other (i.e., two nets at the 4.9 m depth and three nets at the 7.3 m depth) (Figure 6). Each end of a gill net was held in place by a Danforth anchor with the float line attached to buoys.

Experimental Fyke Nets

Our purpose for fishing experimental (portable) fyke nets was to determine the feasibility of sampling outside barrier islands in the Beaufort Sea. Two questions were addressed in 1990. First, is it possible to fish a fyke net outside the barrier islands? Second, would the newly designed nets be able to catch fish? Experimental fyke nets were fished at Camden Bay (stations CP10 and CP11) and Beaufort Lagoon (stations BS10, BS11, BL12 and BL13) in a manner similar to standard fyke nets. Fishing experimental fyke nets was opportunistic based on work load and weather. They were checked once daily unless severe weather precluded safe boat travel.

Experimental fyke nets (Figure 5) were designed to be mobile so a number of areas could be fished. The trap was attached to the wings and anchors with several brass snaps. The method of attachment and the smaller overall size allowed rapid removal of the entire trap in situations where the weather might deteriorate. Fish in the trap could then be processed in a safer location. The nets were constructed with three tandem 1.5-m wide and 1.2-m high frames. Within the tandem frames, a parallel throat system funneled fish through three chambers and into one of two parallel cod ends. The mesh sizes were 12.5-mm stretch for the trap and 25-mm stretch for the wings and lead. The 30-m lead was anchored between the first set of throats with 8-m wings attached to the outside edge of the frame. The nets were anchored similarly to standard fyke nets and in waters of the same depth range. Fish approaching the net were funneled into the cod end on the side from which they approached.

RELATIVE ABUNDANCE AND DISTRIBUTION

Sample Processing

All fish captured were enumerated by species. The number of fish in unusually large catches (>1,000 individuals, usually Arctic cisco and Arctic cod) were estimated by counting the number of fish in three random sub-samples. A sub-sample was defined by the volume required to fill a dip net to a prescribed level. An effort was made to randomly mix the catch prior to

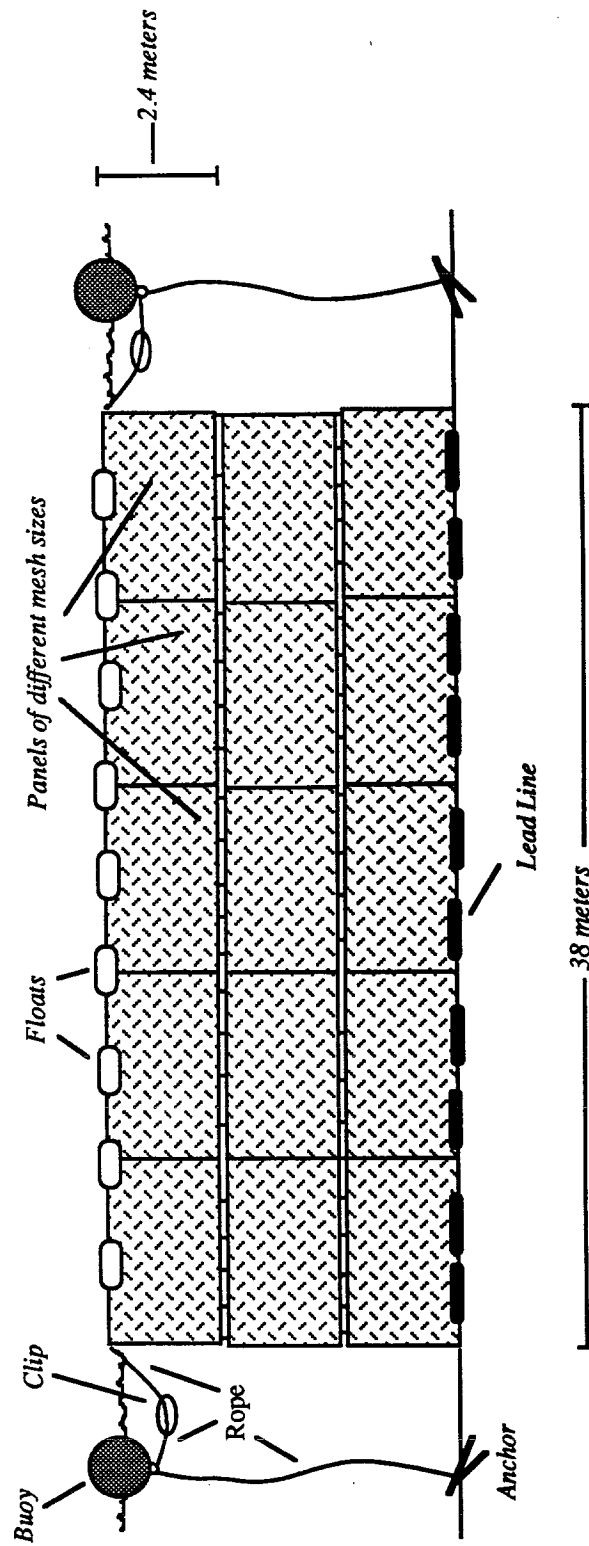


Figure 6.- Gill net configuration used for fishing in 7.3 meters water depth.

obtaining each sub-sample. The average number of fish in the three counted sub-samples was multiplied by the total number of sub-samples to estimate the entire catch. In the case of gill net catches all fish were processed individually, because of low numbers caught. All fish were released except those sacrificed for other analyses. Releases were made offshore, away from the net site to avoid immediate recapture.

Catch Data Analyses

Catches of each species were combined from adjacent fyke net codends at each station for a daily total catch. The daily effort for each species was adjusted to 24 h. Arctic cisco were separated into juveniles and adults using a 200 mm fork length (FL) division. Relative abundance of each species was calculated as catch per unit effort (CPUE) by day (date of net processing), by season at each net station, and by season for each sampling area. Fyke net seasonal mean CPUE was calculated for each station by dividing the summed catch by the summed effort for the season. Sampling area CPUE's were calculated by dividing the summed catch by the summed effort of stations in the sampling area. Daily catch rates are presented for the five target species (Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin and Arctic flounder). Seasonal catch rates are not estimated means so no statistical comparisons are given.

Mean daily gill net CPUE for each station were calculated from the daily catch rates as fish/h. Gill net catches of Arctic cisco were not separated into two groups, following conventions of previous reports (Fruege et al. 1989; Palmer and Dugan 1990). Gill net station mean catch rates and standard deviations for Arctic char and Arctic cisco were calculated and examined for lack of overlap as an indication of differences between station catch rates.

LENGTH FREQUENCY DISTRIBUTIONS

Length frequency distributions for the five target species (Arctic char, Arctic cisco, Arctic cod, fourhorn sculpin, and Arctic flounder) were generated for each study area using standard fyke net data. Fork lengths (FL) were used for Arctic char, Arctic cisco and Arctic cod while total lengths (TL) were measured for fourhorn sculpin and Arctic flounder. Lengths of at least 50 randomly-selected individuals of each species in each net's catch were measured each day to the nearest millimeter. All individuals were measured if total daily catch at each station for a species was 50 or less. In fyke net catches, Arctic cisco larger than 300 mm FL (usually much less numerous than the smaller Arctic cisco and not adequately represented in sub-samples) were measured individually and counted separately from the sub-samples. The division at 300 mm FL was selected because of separation of modal groups at that length (Palmer and Dugan 1990).

Length frequency distributions were generated separately for Arctic char and Arctic cisco caught by gill nets. All fish captured in gill nets were measured as above except that of Arctic cisco were not separated by size. Fyke net length data for each species were plotted by four, approximately two-week periods (July 9-31, August 1-15, August 16-31 and

September 1-14). Gill net length frequency distributions were plotted for the entire season.

WEIGHT-LENGTH RELATIONSHIPS

Data Collection

Weight-length relationships of the five target species were described during two time periods by collecting fish during the early and late portions of the open water season. The two periods were July 10-24 and August 29-September 14. We attempted to equally sample lengths of all fish for a given species by collecting five fish from each length interval during each sampling period. Length intervals were 10 mm except for Arctic char where 25 mm intervals were used because of their larger size range (Anderson and Gutreuter 1983).

Fish lengths were measured as described above. Fish weighing less than 500 g were weighed to the nearest gram with an electronic balance. Fish weights of 500 g or more were determined using Pesola® spring scales to different levels of precision depending upon fish size. Fish weights between 500 g and 1 kg were measured to the nearest 10 g; weights between 1 and 2 kg were measured to the nearest 50 g; and weights greater than 2 kg were measured to the nearest 100 g.

Data Analysis

Weight-length relationships were described for Arctic char, Arctic cisco, Arctic cod, Arctic flounder, and fourhorn sculpin using the growth model

$$W = aL^b,$$

where a and b are constants derived from regressing the logarithm (base 10) of weight (W) on the logarithm (base 10) of length (Ricker 1975). Functional regressions (slopes and intercepts) were calculated using the geometric mean (GM) regression technique (Ricker 1973, 1975). To determine if early and late data could be pooled, slopes and intercepts were tested for equality using analysis of covariance procedure (SAS 1988). Weight-length relationships (functional regressions) of species with significant differences ($\alpha=0.05$) in either slope or intercept were calculated and graphed separately.

FISH CONDITION

Relative condition of fish (weight of a fish at a given length) was compared for the five target species by least square regression (Cone 1989). Comparisons of condition between fish collected early in the open water season and those collected late in the season were tested using analysis of covariance ($\alpha = 0.05$). Weight and length data used to calculate the functional regression, above, were used for analysis of relative fish condition. The least squares regression was calculated using the SAS GLM analysis of covariance procedure (SAS 1988). A natural logarithm

transformation was done to linearize the data and stabilize the variance as suggested by Gazey (W.J. Gazey, Gazey Research, personal communication). The procedure allowed separate evaluations of slopes and intercepts.

INSTANTANEOUS GROWTH

Arctic cisco otoliths were collected to document mean lengths at age and to determine instantaneous growth during the open water season for ages 0-4. Collections were made during the time periods used to gather weight-length data (July 10-24 and August 29-September 14). We attempted to obtain eight otoliths from each 10 mm size interval. Otoliths were removed, stored in isopropyl alcohol, and aged in the laboratory after the field season. Whole otoliths were illuminated with a fiber optic light and viewed at low magnification through a dissecting microscope. If ages could not be assigned using surface reading techniques, otoliths were broken through the nucleus and burned in an alcohol flame before viewing (Barber and McFarlane 1987). Ages were assigned based on at least two independent readings. When the two readers could not agree, a third reader was used. If disagreements persisted, the otolith was excluded.

Initial (W_1) and final weights (W_2) for early and late season fish, respectively, were estimated from the mean length of aged fish using the functional regression weight-length relationship described in the "Weight-Length" section above. Instantaneous growth (G) (Bagnel and Tesch 1978) was calculated as follows:

$$G = \text{Log}_e(w_2) - \text{Log}_e(w_1) / \Delta t$$

Change in time, Δt , is arbitrary and is defined for our purpose as the time interval between the mid-points of the early and late sampling periods, approximately 50 days.

FISH MOVEMENTS

Juvenile Arctic cisco and Arctic char less than 300 mm FL were marked using India ink dye applied with a high pressure Syrijet® dental injector (Mizzy, Inc.). Fish marked at the three different study sites were distinguished by applying dye at the base of different fins as follows: Camden Bay, left pelvic; Beaufort Lagoon, right pelvic; Kaktovik and Jago lagoons, left caudal peduncle. Arctic char and Arctic cisco greater than 300 mm FL and other target species greater than 200 mm in length were tagged with Floy® anchor type tags. Dye marks, tag numbers, weight (during the two periods when weight were being collected), and fish length from recaptured individuals were recorded at the time of capture.

HYDROGRAPHIC AND METEOROLOGIC SAMPLING

Depth profiles of salinity and temperature were collected at specific hydrographic stations using electronic conductivity-temperature-depth (CTD) recorders (Table 1 and Figures 2-4). These data were also collected at all fyke and gill net stations when nets were checked. At Camden Bay (stations CB02 and CB06) and offshore at Beaufort Lagoon (Station BS02 and BS03) continuous records of salinity, temperature, current direction, and current velocity were collected using moored current meters. Measurements of air temperature, wind direction, wind velocity, and barometric pressure were recorded at Camden Bay and Beaufort Lagoon with portable meteorological stations. A separate progress report, similar to those of Hale (1990, 1991), will contain more detailed descriptions of hydrographic and meteorologic methods of data collection, equipment used, summaries and data analyses.

RESULTS

RELATIVE ABUNDANCE AND DISTRIBUTION

Standard Fyke Nets

During the 1990 field season, fyke nets were fished for varying numbers of days at the eight historically fished stations (Table 1 and Figures 2-4). Occasional storms kept crews from working and destroyed nets causing variation in the number of days fished at each station. The first nets were operational July 9 and the last nets were removed September 14, 1990. The total number of sampling days at the net stations were as follows: Camden Bay, SC01 54 d and SC04 51 d; Kaktovik and Jago lagoons, KL05 49 d, KL10 55 d, JL12 46 d, JL14 47 d; Beaufort Lagoon, BL02 61 d and BL04 47 d.

Twenty-one species of fish were identified in standard fyke net catches in nearshore Arctic Refuge waters (Table 2). Small Arctic cisco (≤ 200 mm FL) made up 39% of the total catch and were the most numerous (Table 3). The next most numerous species collected were Arctic cod (29%), fourhorn sculpin (14%), Arctic flounder (9%) and capelin (4%). Catch per unit effort (fish/d) reflected the same overall trends as total catch (Table 4).

Sampling areas.— In Camden Bay, 20 species of fish were identified. Arctic cod made up 66% of the total catch (Table 3). The next most numerous species were fourhorn sculpin (13%), capelin (9%), small Arctic cisco (≤ 200 mm FL) (4%), Arctic flounder (3%) and Arctic char (1%). Seventy percent of the total catch was from station SC01, due to the large catch of Arctic cod and capelin. Area catch rates for Arctic cod, fourhorn sculpin, Arctic char, large Arctic cisco (> 200 mm FL), and capelin were the highest of the sampling areas (Table 4). Arctic cod (1,098 fish/d), capelin, large Arctic cisco and Arctic char were more prevalent at station SC01 than at SC04. Small Arctic cisco were most abundant at station SC04.

In Kaktovik Lagoon, 17 species of fish were identified. Small Arctic cisco (≤ 200 mm FL) made up 57% of the total catch (Table 3). The next most abundant species were fourhorn sculpin (16%), Arctic flounder (11%), ninespine stickleback (8%) and Arctic cod (4%). The majority of the total catch (80%) was from station KL05. Area catch rates for Arctic char (7 fish/d) and large Arctic cisco (1 fish/d) were lower than Camden Bay, comparable to Jago Lagoon and higher than Beaufort Lagoon (Table 4). Small Arctic cisco (≤ 200 mm FL) station catch rates (Table 4) were higher at KL05 (513 fish/d) than at KL10 (34 fish/d). Station catch rates of Arctic cod, fourhorn sculpin and ninespine stickleback at KL05 were at least twice that of KL10.

In Jago Lagoon, 16 species of fish were identified. Small Arctic cisco (≤ 200 mm FL) made up 69% of the total catch. Fourhorn sculpin (14%), Arctic flounder (10%), ninespine stickleback (3%) and Arctic char (1%) were the next most abundant species in the total catch (Table 3). The small Arctic cisco area catch rate (478 fish/d) was the highest of the study areas. Area catch rates were low for large Arctic cisco (1 fish/d) and Arctic cod (4 fish/d).

TABLE 2.- Fish species captured in Arctic Refuge coastal waters during July-September 1990. An Arctic grayling and one chum salmon were caught only in an experimental fyke net and a gill net, respectively.

Family	Common name	Scientific name
Anadromous		
Salmonidae	Arctic cisco	<i>Coregonus autumnalis</i>
	Least cisco	<i>Coregonus sardinella</i>
	Broad whitefish	<i>Coregonus nasus</i>
	Arctic char	<i>Salvelinus alpinus</i>
	Chum salmon	<i>Oncorhynchus keta</i>
	Pink salmon	<i>Oncorhynchus gorbuscha</i>
Osmeridae	Rainbow smelt	<i>Osmerus mordax</i>
Gasterosteidae	Ninespine stickleback	<i>Pungitius pungitius</i>
Freshwater		
Salmonidae	Arctic grayling	<i>Thymallus arcticus</i>
	Round whitefish	<i>Prosopium cylindraceum</i>
Marine		
Anarhichadidae	Bering Wolffish	<i>Anarhichas orientalis</i>
Clupeidae	Pacific herring	<i>Clupea harengus</i>
Osmeridae	Capelin	<i>Mallotus villosus</i>
Gadidae	Arctic cod	<i>Boreogadus saida</i>
	Saffron cod	<i>Eleginus gracilis</i>
Stichaeidae	Slender eelblenny	<i>Lumpenus fabricii</i>
Ammodytidae	Pacific sand lance	<i>Ammodytes hexapterus</i>
Cottidae	Fourhorn sculpin	<i>Myoxocephalus quadricornis</i>
	Arctic sculpin	<i>Myoxocephalus scorpioides</i>
	Arctic staghorn sculpin	<i>Gymnocanthus tricuspidis</i>
	Arctic hookear sculpin	<i>Arctediellus uncinatus</i>
Cyclopteridae	Greenland seasnail	<i>Liparis tunicatus</i>
Pleuronectidae	Arctic flounder	<i>Liopsetta glacialis</i>

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

TABLE 3.— Total standard fyke net catch by sampling station in Arctic Refuge coastal waters, July-September 1990.

September 1990.

Species	Sampling area										Total
	Camden Bay		Kaktovik Lagoon		Jago Lagoon		Beaufort Lagoon				
	SC01	SC04	KL05	KL10	JL12	JL14	BL02	BL04			
Arctic Cod	61,857	19,814	1,640	370	86	265	26	0		84,058	
Fourhorn sculpin	6,717	9,258	5,611	3,406	5,070	5,046	5,970	435		41,513	
Ninespine stickleback	227	158	3,143	1,270	567	1,557	323	20		7,265	
Arctic flounder	1,651	2,501	3,382	2,683	2,241	4,850	7,183	981		25,472	
Arctic cisco (≤ 200 mm)	1,940	3,015	28,725	2,181	23,227	25,002	30,366	1,901		116,355	
Arctic cisco (> 200 mm)	412	204	131	29	45	68	9	63		961	
Arctic char	1,091	510	532	347	209	504	128	48		3,369	
Saffron cod	290	292	327	391	202	251	70	46		1,869	
Rainbow smelt	124	528	63	20	55	147	17	4		958	
Slender eelblenny	72	0	38	21	2	1	6	7		147	
Arctic sculpin	52	4	16	39	149	25	289	31		605	
Broad whitefish	5	1	0	0	0	0	2	0		8	
Least cisco	578	240	24	27	30	32	3	10		944	
Pacific herring	3	0	16	7	4	6	1	0		37	
Pink salmon	2	1	0	5	1	1	0	0		10	
Capelin	11,125	30	3	3	9	8	0	0		11,178	
Arctic grayling	0	0	0	0	0	0	0	0		0	
Arctic hooker sculpin	1	0	0	0	0	0	0	0		1	
Arctic staghorn sculpin	0	0	0	2	0	0	0	0		2	
Round whitefish	1	0	0	0	0	0	0	0		1	
Greenland seasnail	61	58	1	0	1	0	0	2		123	
Pacific sand lance	1	0	4	0	1	0	0	0		6	
Bering Wolffish	1	0	0	0	0	0	0	0		1	
Unidentified sculpin	0	0	1	0	1	0	0	0		2	
Unidentified smelt	2	0	0	0	0	0	0	0		2	
Total	86,213	36,614	43,647	10,801	31,900	37,763	44,393	3,548		294,887	

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

TABLE 4.- Seasonal catch per unit effort (fish/d) by standard fyke net sampling stations in Arctic Refuge coastal waters, July - September 1990. Sample area mean is calculated from all daily CPUE.

	Sampling areas											
	Camden Bay			Kaktovik Lagoon			Jago Lagoon			Beaufort Lagoon		
	SC01	SC04	Area	KL05	KL10	Area	JL12	JL14	Area	BL02	BL04	Area
Arctic cod	1098.2	351.6	724.8	29.3	5.7	16.7	1.9	4.9	3.5	0.4	0	0.2
Fourhorn sculpin	119.2	164.3	141.8	100.1	52.7	74.8	109.5	92.5	100.3	95.7	8.8	57.4
Ninespine stickleback	4.0	2.8	3.4	56.1	19.7	36.6	12.2	28.6	21.1	5.2	0.4	3.1
Arctic flounder	29.3	44.4	36.8	60.4	41.5	50.3	48.4	88.9	70.3	115.1	19.9	73.1
Arctic cisco (≤200mm)	34.4	53.5	44.0	512.7	33.8	256.2	501.6	458.5	478.3	486.8	38.6	289.1
Arctic cisco (>200mm)	7.3	3.6	5.5	2.3	0.4	1.3	1.0	1.2	1.1	0.1	1.3	0.6
Arctic char	19.4	9.0	14.2	9.5	5.4	7.3	4.5	9.2	7.1	2.0	1.0	1.6
Saffron cod	5.2	5.2	5.2	5.8	6.0	6.0	4.4	4.6	4.5	1.1	0.9	1.0
Rainbow smelt	2.2	9.4	5.8	1.1	0.3	0.7	1.2	2.7	2.0	0.3	0.1	0.2
Slender eelblenny	1.3	0	0.6	0.7	0.3	0.5	<0.1	<0.1	<0.1	0.1	0.1	0.1
Arctic sculpin	0.9	0.1	0.5	0.3	0.6	0.4	3.2	0.4	1.7	4.6	0.6	2.9
Broad whitefish	0.1	<0.1	<0.1	0	0	0	0	0	0	<0.1	0	<0.1
Least cisco	10.3	4.2	7.3	0.4	0.4	0.4	0.6	0.6	0.6	<0.1	0.2	0.1
Pacific herring	<0.1	0	<0.1	0.3	0.1	0.2	0.1	0.1	0.1	<0.1	0	<0.1
Pink salmon	<0.1	<0.1	<0.1	0	0.1	<0.1	<0.1	<0.1	<0.1	0	0	0
Capelin	197.5	0.5	99.0	<0.1	<0.1	<0.1	0.2	0.1	0.2	0	0	0
Arctic grayling	0	0	0	0	0	0	0	0	0	0	0	0
Arctic hookear sculpin	<0.1	0	<0.1	0	0	0	0	0	0	0	0	0
Arctic staghorn sculpin	0	0	0	0	<0.1	<0.1	0	0	0	0	0	0
Round whitefish	<0.1	0	<0.1	0	0	0	0	0	0	0	0	0
Greenland seasnail	1.1	1.0	1.0	<0.1	0	<0.1	<0.1	0	<0.1	0	<0.1	<0.1
Pacific sand lance	<0.1	0	<0.1	<0.1	0	<0.1	<0.1	0	<0.1	0	0	0
Bering wolffish	<0.1	0	<0.1	0	0	0	0	0	0	0	0	0
Unidentified sculpin	0	0	<0.1	<0.1	0	<0.1	<0.1	0	<0.1	0	0	0
Unidentified smelt	<0.1	0	<0.1	0	0	0	0	0	0	0	0	0

Arctic char were twice as abundant at station JL14 (9 fish/d) than JL12 (4 fish/d).

In Beaufort Lagoon, 14 species were identified. Small Arctic cisco (≤ 200 mm FL) made up 63% of the total catch (Table 3). The next most abundant species were Arctic flounder (17%), fourhorn sculpin (13%) and ninespine stickleback ($< 1\%$). Arctic char, Arctic cod and large Arctic cisco (> 200 mm FL) combined, made up less than 1% of the total catch. Catches from station BL02 comprised 92% of the total. Area catch rates were moderate for small Arctic cisco (289 fish/d), but the station catch rate at BL02 was the second highest (487 fish/d).

Target species.— Temporal and spatial trends in relative abundance were apparent for some target species. Arctic char daily catch rates varied widely ranging from 0-150 fish/d (Figures 7-9) in the three sampling areas. Few Arctic char were present in September, but no other temporal trends were observed. Sampling area catch rates were highest at Camden Bay, 14 fish/d, and lowest at Beaufort Lagoon, 2 fish/d (Table 4). Area catch rates of Arctic char averaged 7 fish/d in Kaktovik and Jago lagoons. Station SC01, in Camden Bay, had the highest station catch rate, 19 fish/d, but station KL05 had the highest daily catch rate, ~150 fish/d. Daily catch rates for Arctic char were high in mid-July at SC01 and KL05 (Figures 7 and 8).

Small Arctic cisco (≤ 200 mm FL) daily catch rates ranged from 0 to nearly 8,000 fish/d (Figures 10-12). The first influx of large numbers of small Arctic cisco occurred progressively later at more westerly sampling areas. Daily catches over 100 fish/d first occurred in Beaufort Lagoon on July 14, at Kaktovik and Jago lagoons on July 31, and at Camden Bay on August 4. Small Arctic cisco (≤ 200 mm FL) area catch rates were highly variable between sampling areas, ranging from 44 fish/d in Camden Bay to 478 fish/d in Jago Lagoon (Table 4). Station catch rates varied widely. At Camden Bay both SC01 and SC04 had relatively low station catch rates. Kaktovik and Beaufort lagoons each had one station with a relatively high catch rate. In Jago Lagoon both stations exhibited relatively high catch rates (Table 4). Daily catch rates showed no consistent trend except that catch at each station was generally low early in the season, then increased in magnitude and variability, and later decreased (Figures 10-12).

Daily catch rates of large Arctic cisco (> 200 mm FL) varied widely ranging from 0 to 47 fish/d (Figures 13-15). Daily catch rates were generally highest in July, and decreased to zero in September (Figure 13). In Beaufort Lagoon station BL02 daily catch rates were zero after July 26. At station BL04 daily catch rates generally increased at the end of August. Area catch rates ranged from < 1 fish/d at Beaufort Lagoon to 6 fish/d at Camden Bay (Table 4).

Arctic cod daily catch rates were usually less than 20 fish/d with a few significant exceptions (Figures 16-18). Camden Bay had one daily catch rate greater than 60,000 fish/d at SC01 and greater than 18,000 fish/d at SC04 (Figure 16). A few daily observations greater than 500 fish/d strongly

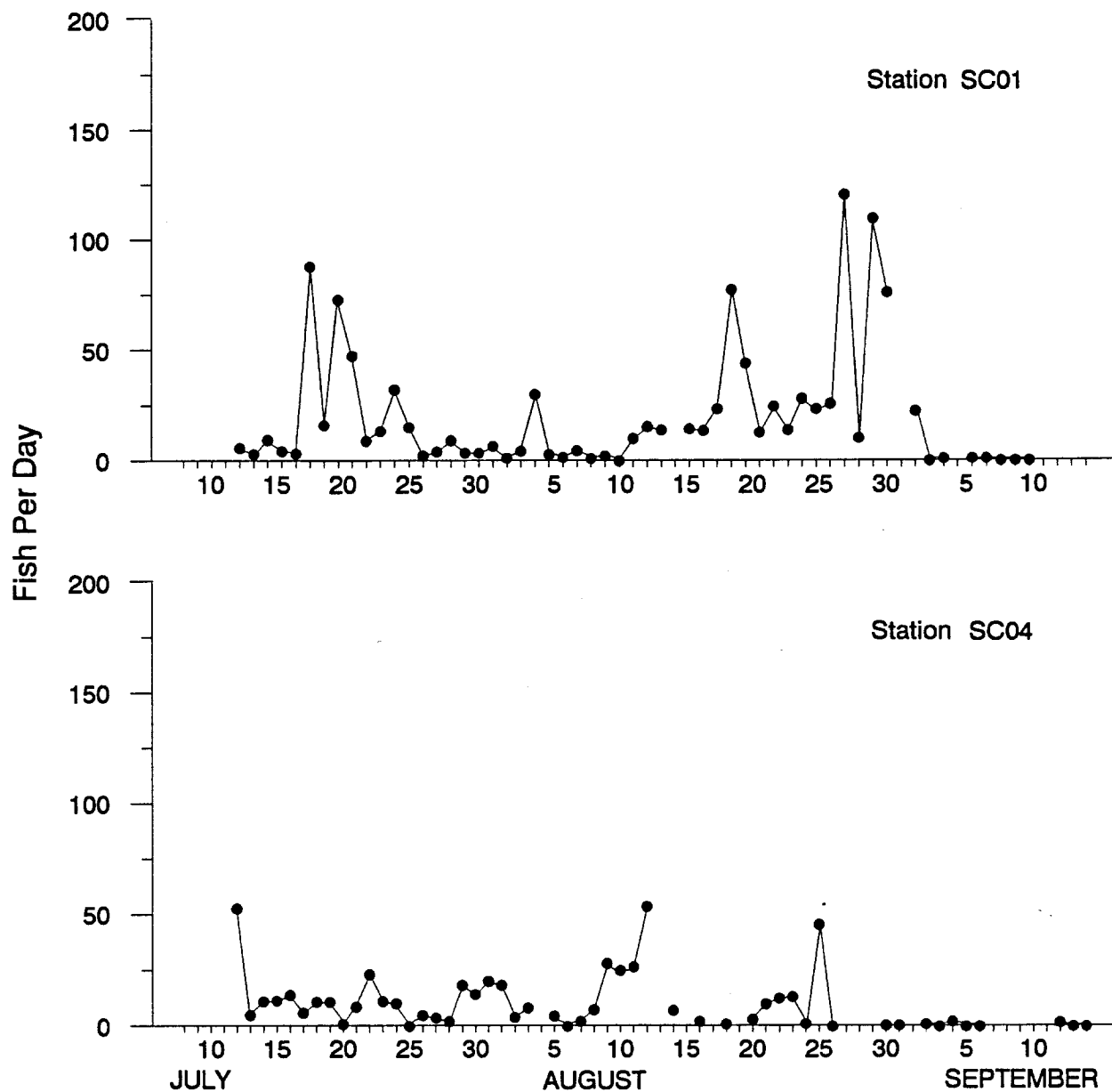


FIGURE 7.- Daily catch per unit effort (fish/d) for Arctic char at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.

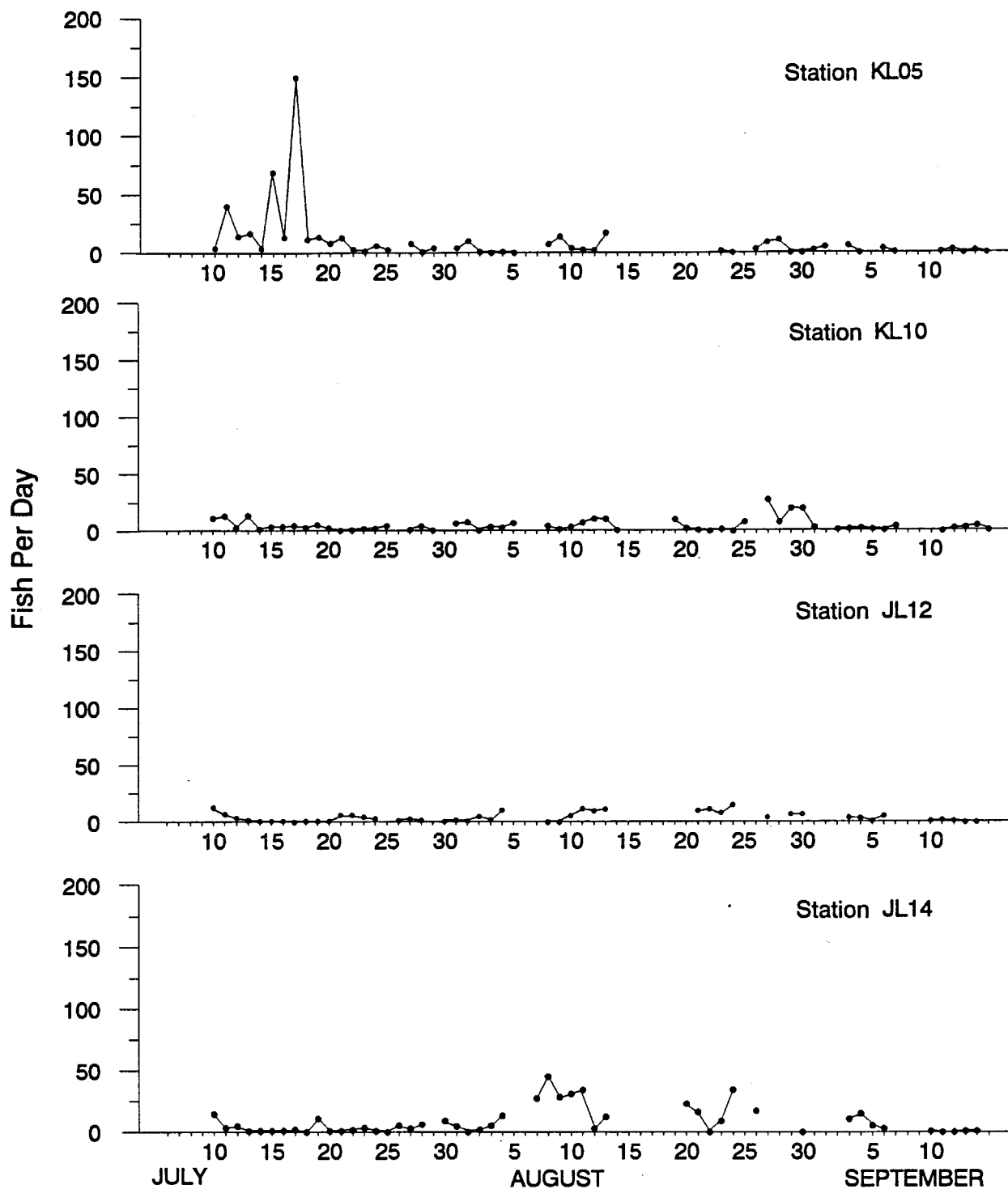


FIGURE 8.- Daily catch per unit effort (fish/d) for Arctic char at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.

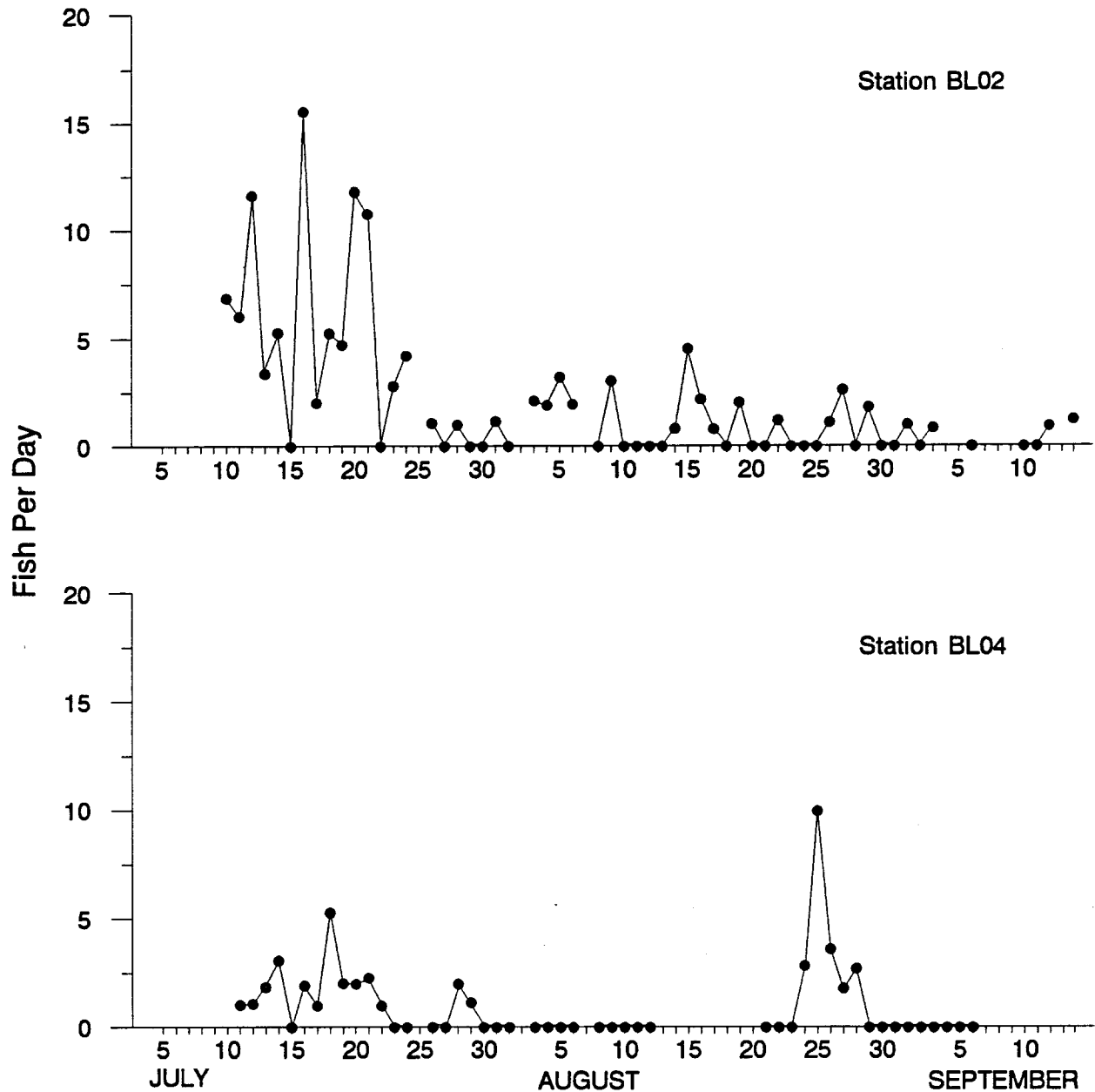


FIGURE 9.— Daily catch per unit effort (fish/d) for Arctic char at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.

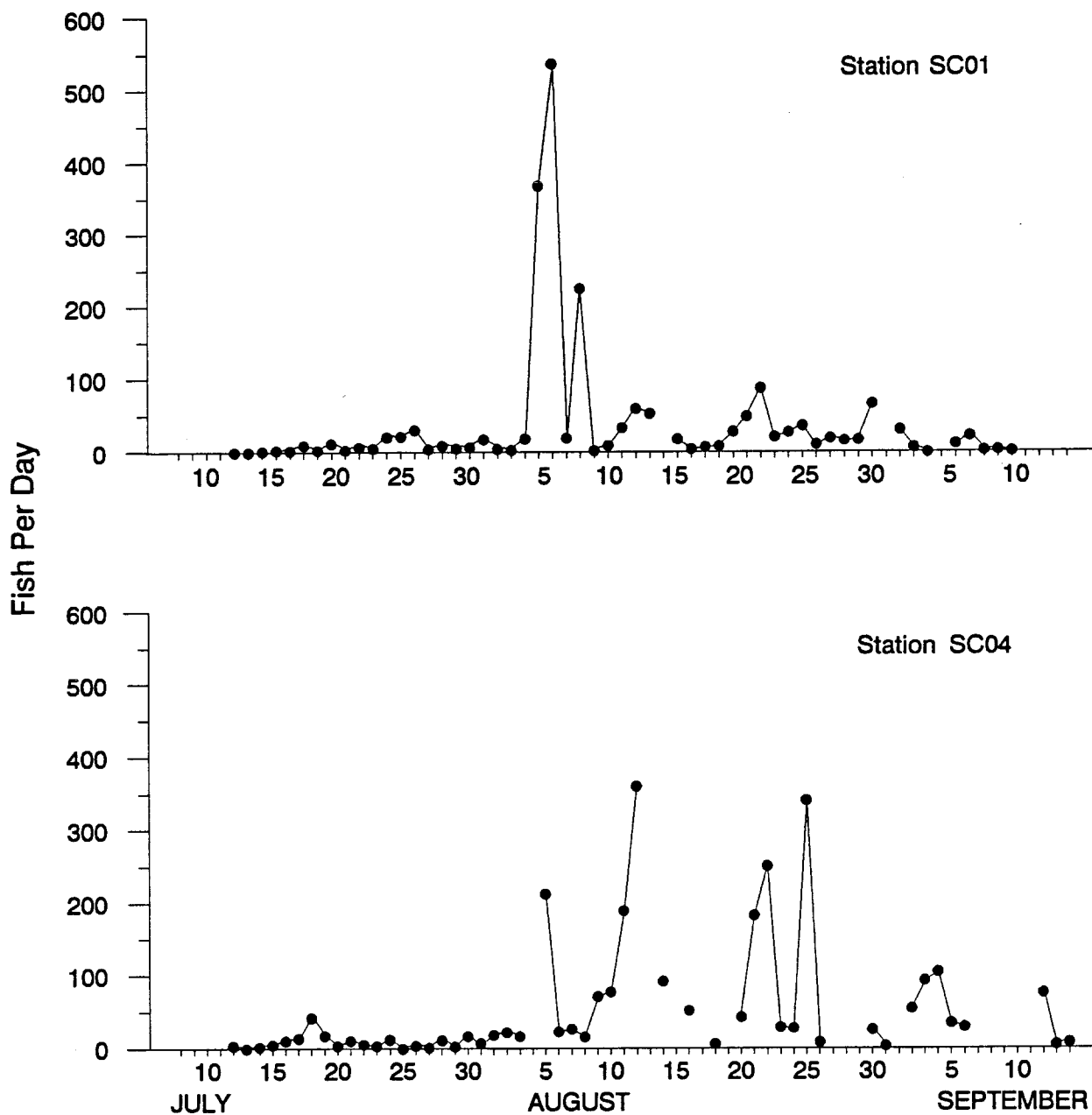
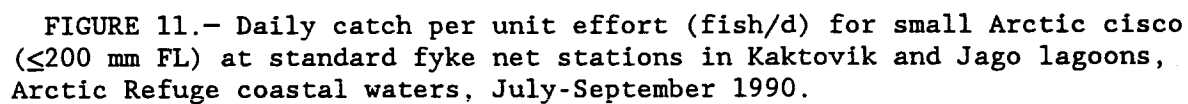


FIGURE 10.— Daily catch per unit effort (fish/d) for small Arctic cisco (≤ 200 mm FL) at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.



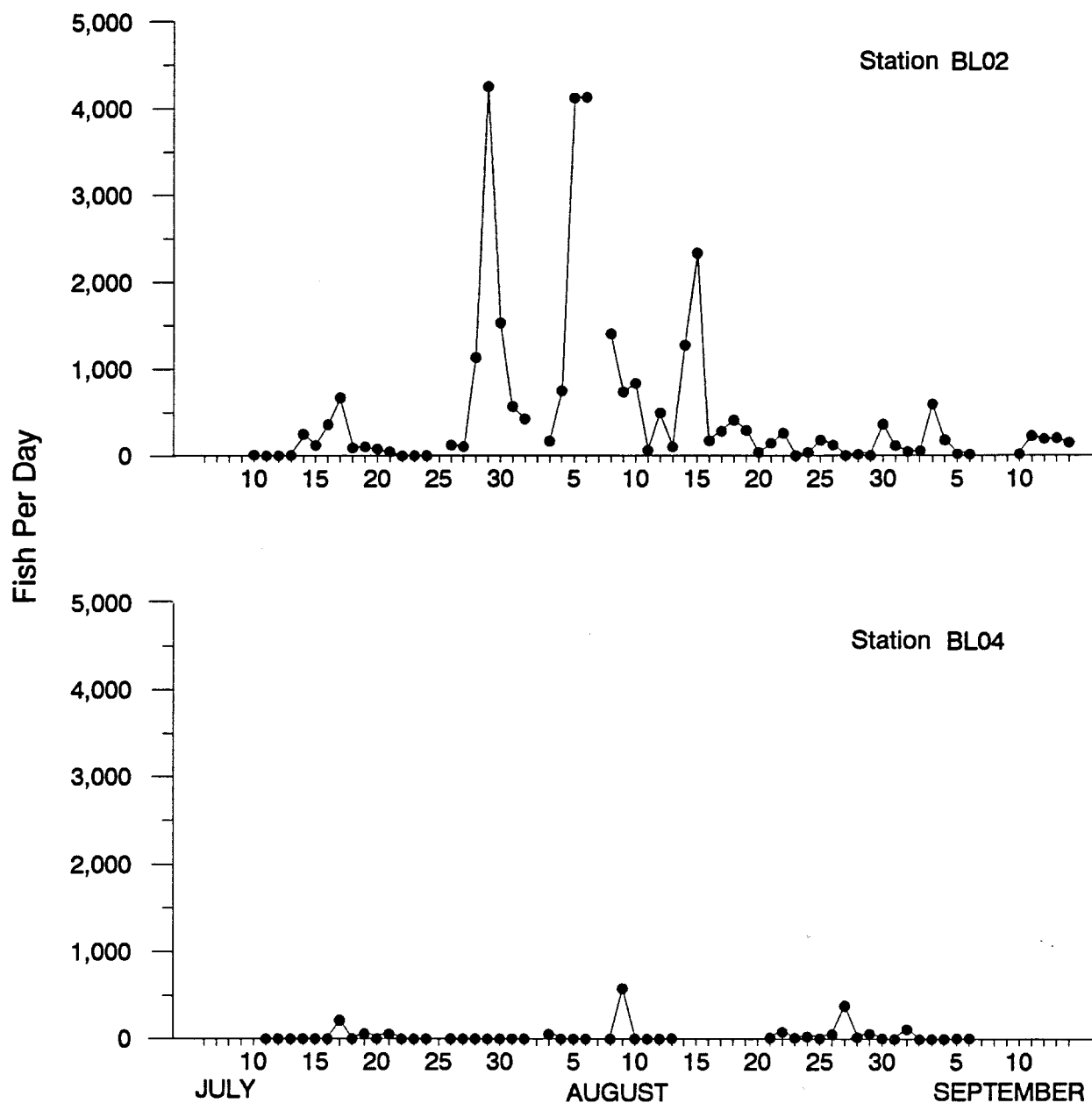


FIGURE 12.- Daily catch per unit effort (fish/d) for small Arctic cisco (≤ 200 mm FL) at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.

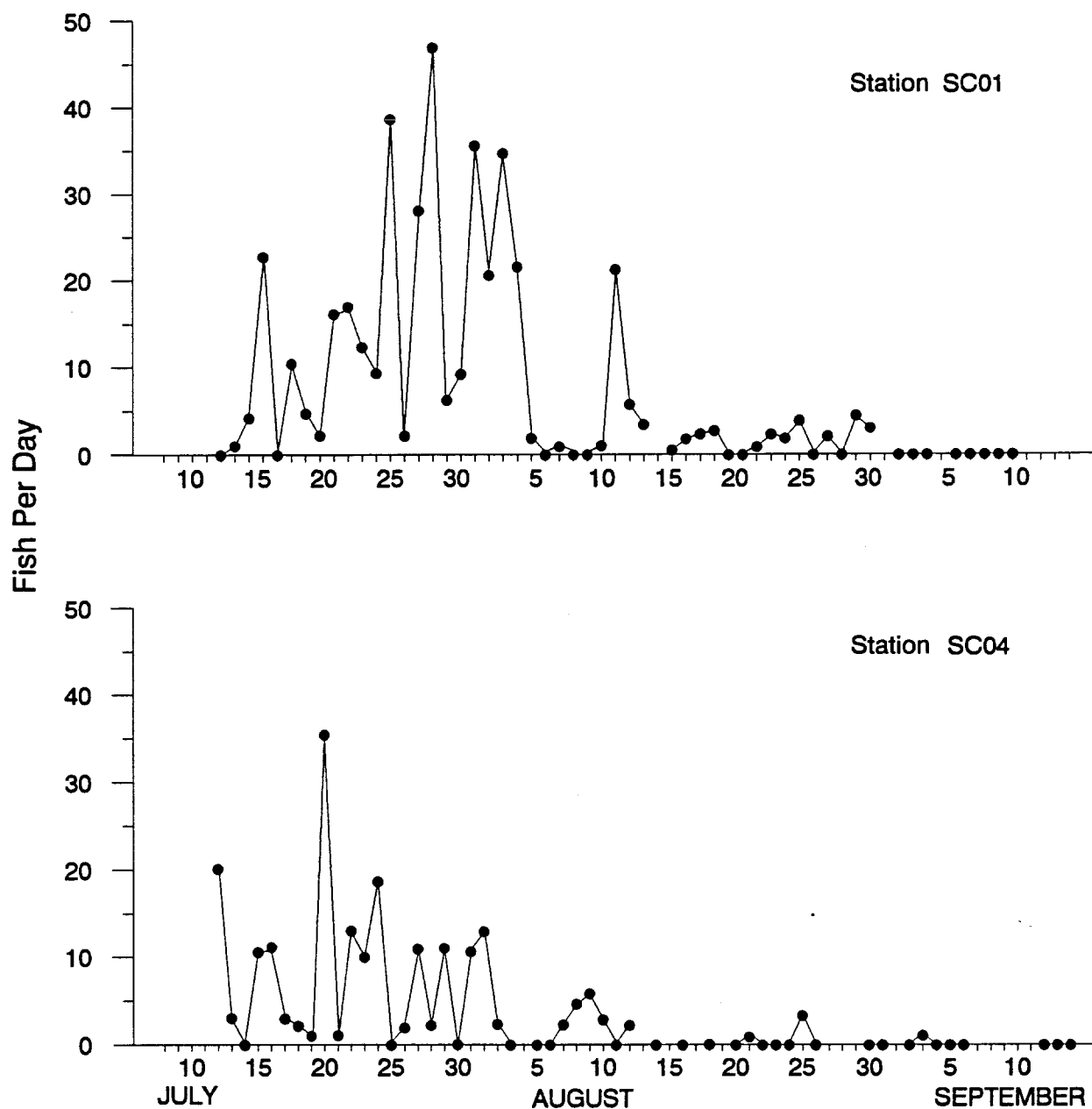


FIGURE 13.- Daily catch per unit effort (fish/d) for large Arctic cisco (>200 mm FL) at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.

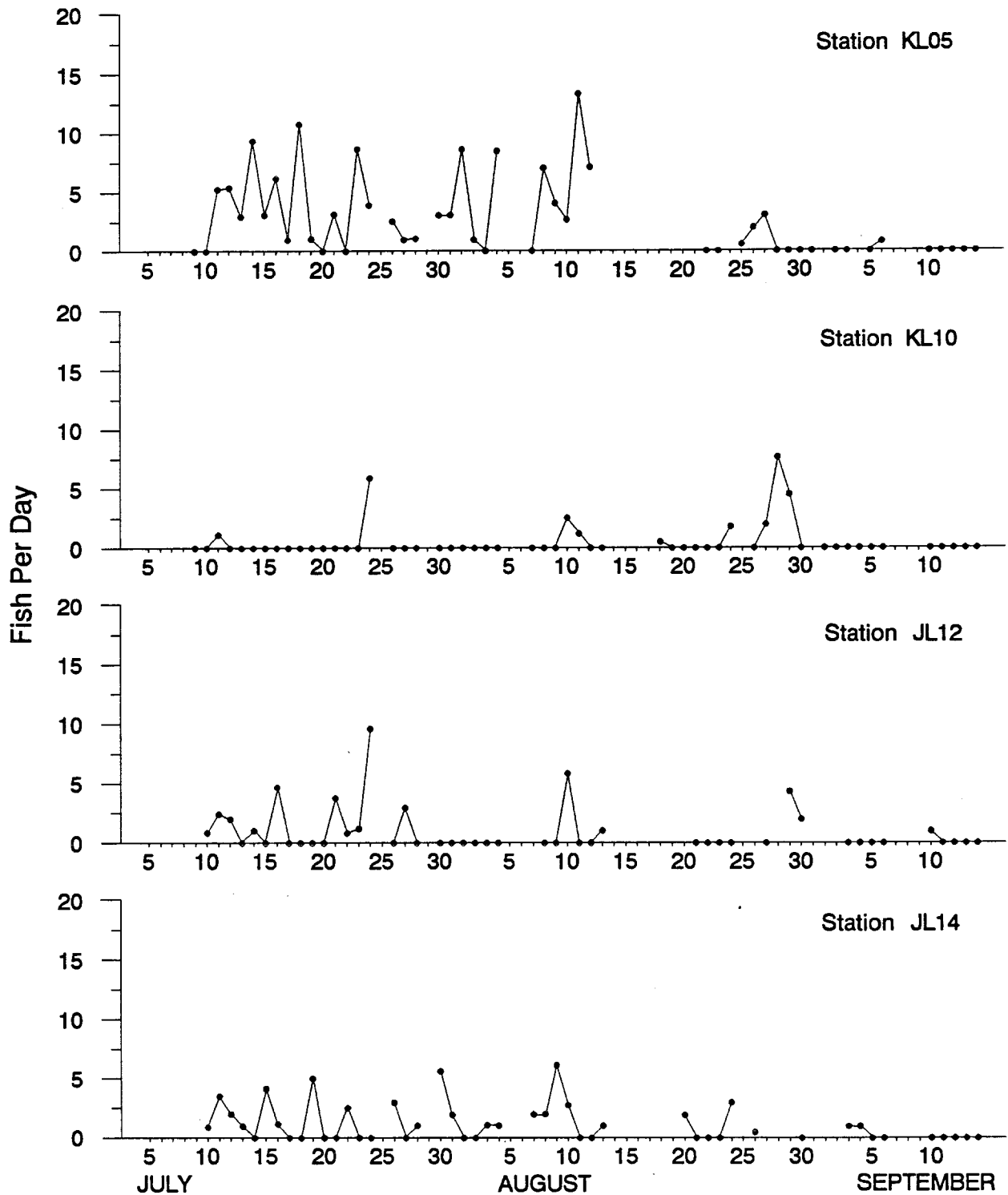


FIGURE 14.- Daily catch per unit effort (fish/d) for large Arctic cisco (>200 mm FL) at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.

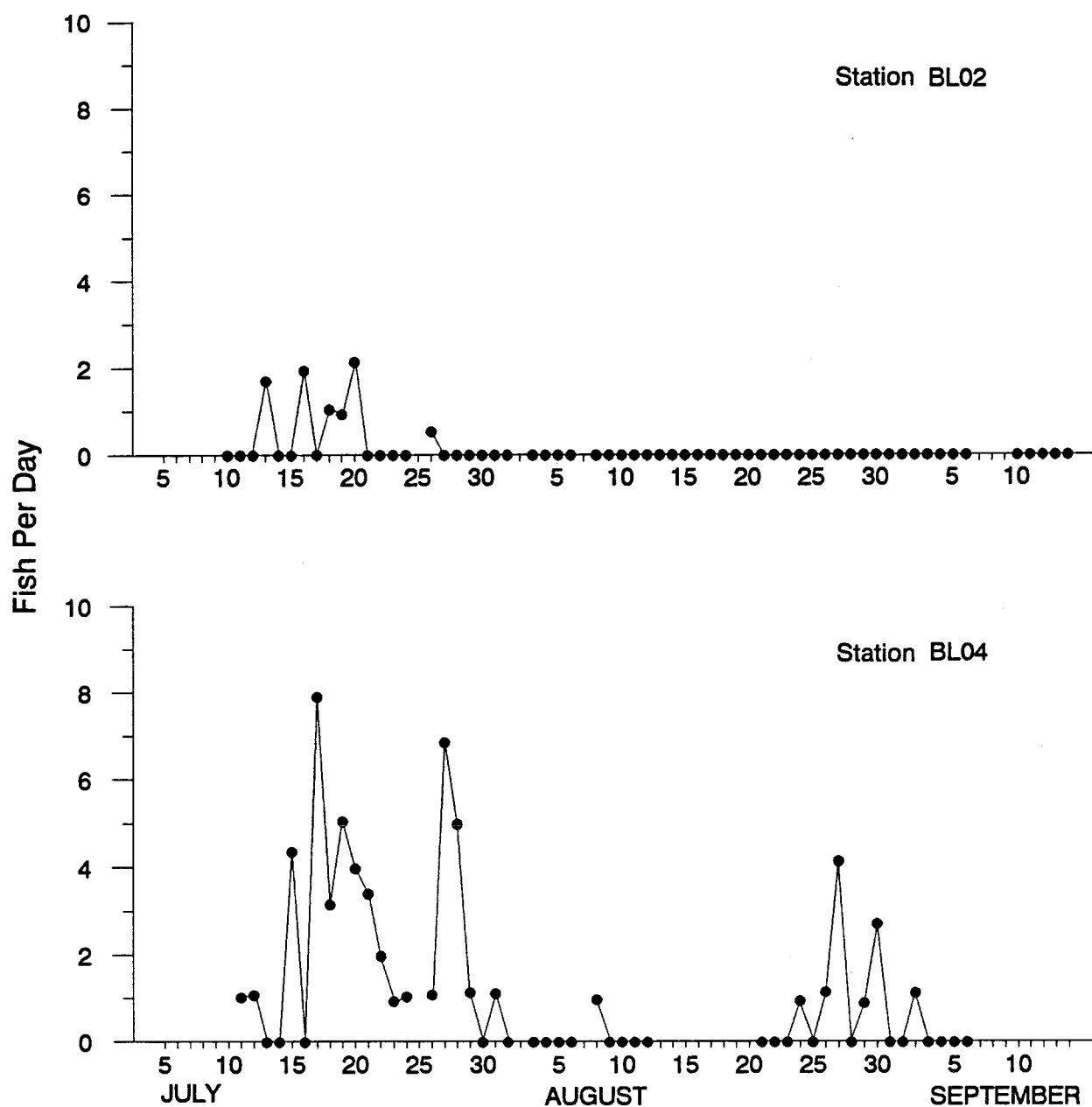


FIGURE 15.— Daily catch per unit effort (fish/d) for large Arctic cisco (>200 mm FL) at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.

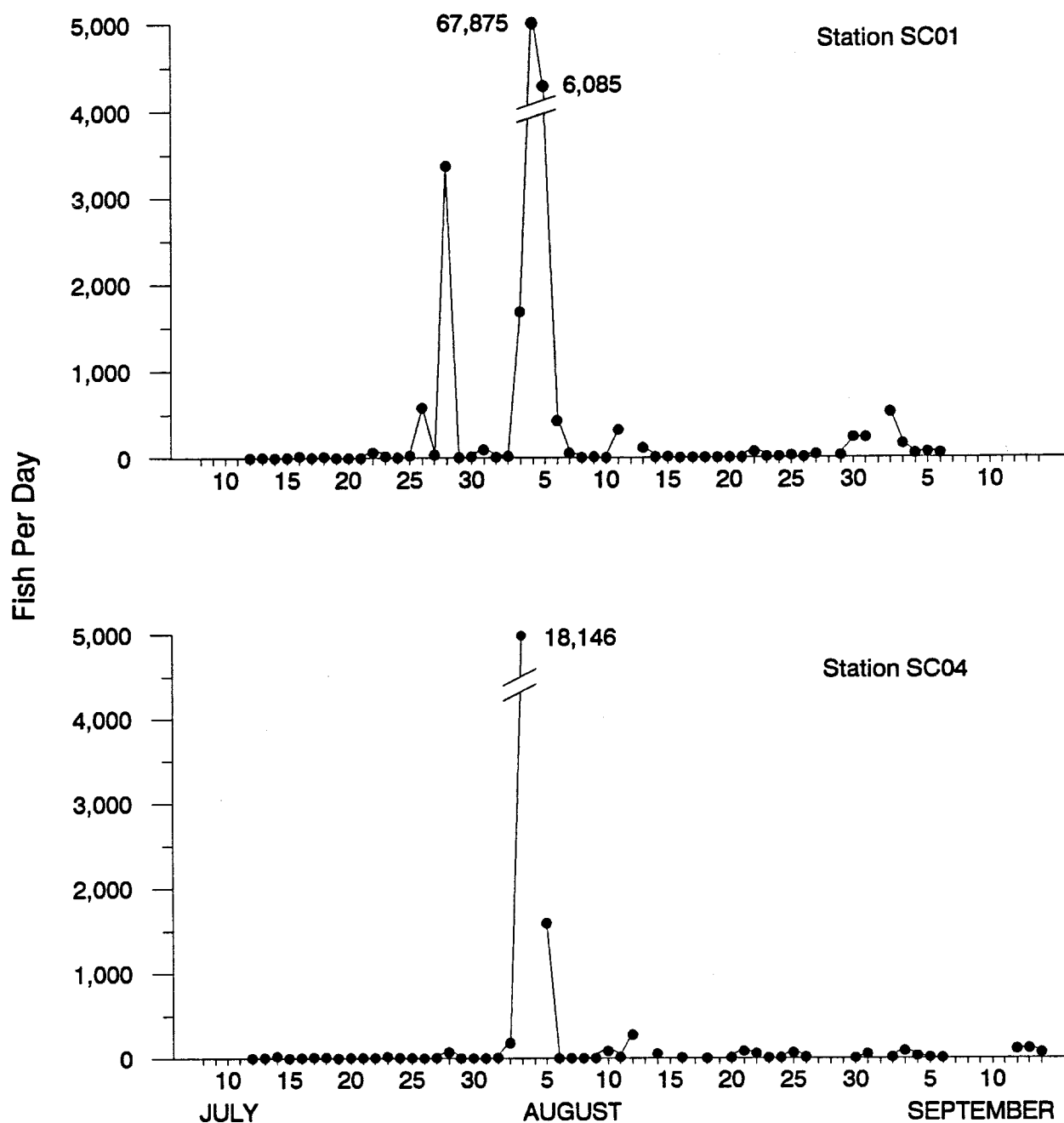
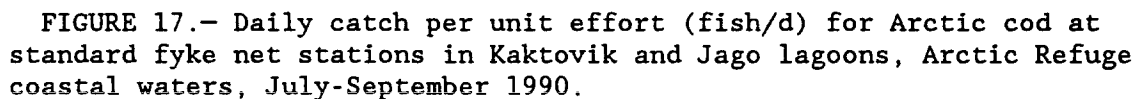


FIGURE 16.— Daily catch per unit effort (fish/d) for Arctic cod at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.



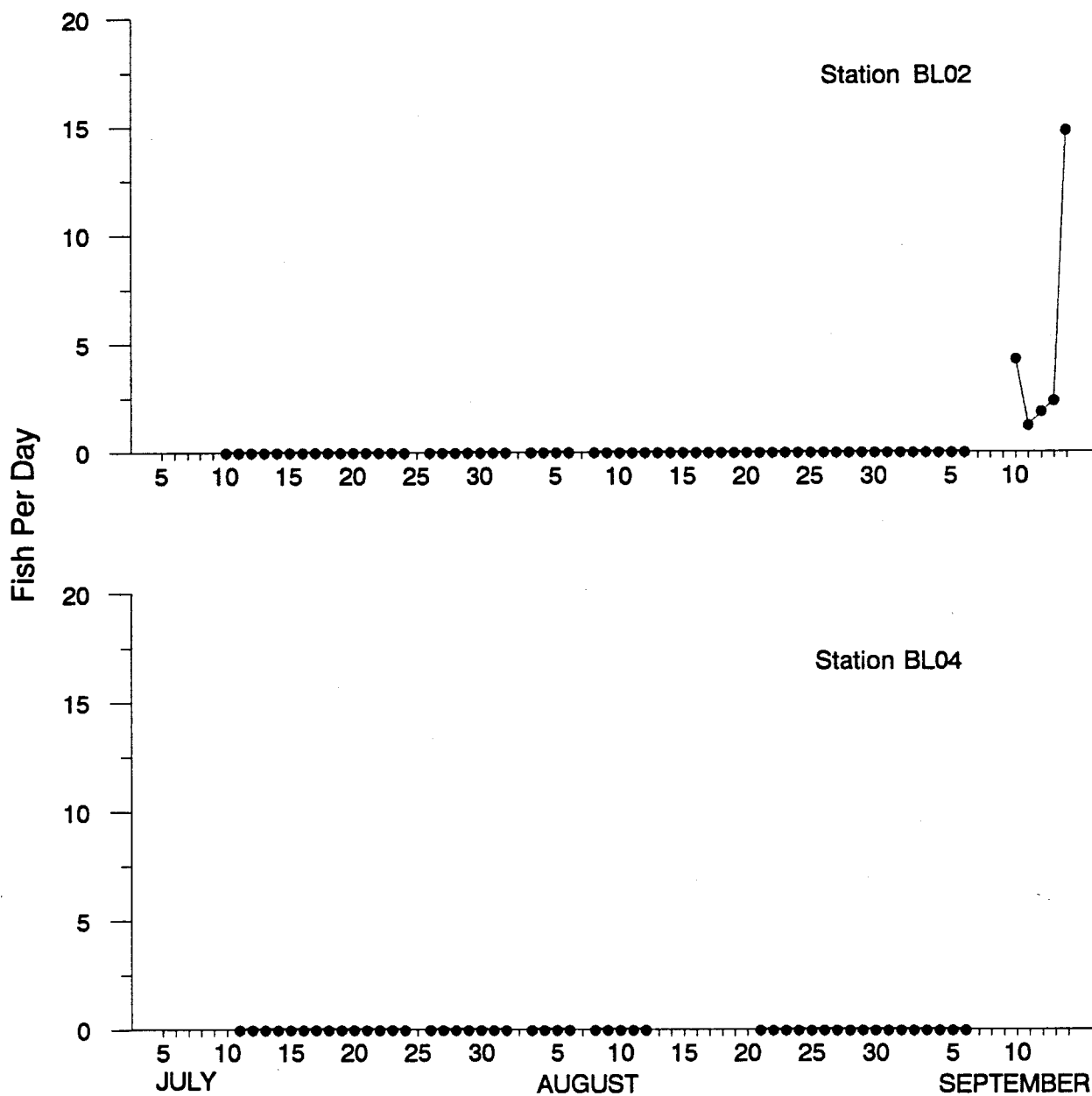


FIGURE 18.— Daily catch per unit effort (fish/d) for Arctic cod at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.

influenced the Camden Bay sampling area catch rates: at SC01 July 26 (579), July 28 (3,369), August 3 (1,682), August 4 (67,875), August 5 (6,086), September 2 (522); and at SC04 August 3 (18,147), and August 5 (1,587) (Figures 16-18). The second highest area catch rate for Arctic cod occurred at Kaktovik Lagoon (17 fish/d) (Table 4) followed by Jago (4 fish/d) and Beaufort lagoons 0.2 fish/d. In Kaktovik and Beaufort lagoons daily catch rates increased late in the season (Figures 17 and 18). Station BL02 did not catch any Arctic cod until the last five sampling days. No Arctic cod were captured at station BL04 (Figure 18).

Fourhorn sculpin daily catch rates ranged from 0 to greater than 1,000 fish/d (Figures 19-21). Daily catch rates were highly variable at all stations and did not exhibit consistent trends in temporal or spatial distribution. Area catch rates ranged from 57 to 142 fish/d at the four sampling areas (Table 4). Camden Bay had the highest relative abundance and Beaufort Lagoon the lowest, based on area catch rates. Station BL02 had a station catch rate of 96 fish/d and was comparable to other sampling areas. BL04 had the lowest station catch rate reducing the Beaufort Lagoon area catch rate to the lowest of the four sampling areas.

Arctic flounder daily catch rates were highly variable throughout the season ranging from 0 to greater than 650 fish/d (Figures 22-24). Catch rates were generally lower, however, late in the season. Arctic flounder were relatively abundant in all sampling areas with area catch rates ranging from 37 fish/d in Camden Bay to 73 fish/d in Beaufort Lagoon (Table 4). The highest station catch rate for the eight net stations was BL02 (115 fish/d) while BL04 had the lowest (20 fish/d), demonstrating high variability among stations within a sampling area. Daily catch rates in excess of 500 fish/d occurred on three occasions at BL02 and once at SC01 in Camden Bay (Figures 22-24).

Gill Nets

A total of 210 fish were caught in 39 replicates of gill net sets in Camden Bay during 1990 (Table 5). Species composition was as follows: 181 Arctic char, 27 Arctic cisco, 1 chum salmon and 1 Pacific herring. Duration of net sets ranged from 1 to 26 hours and averaged 5.5 hours. Standard deviations of mean catch rates for Arctic char and Arctic cisco (Tables 6 and 7) overlap indicating no difference between stations (depth contours). However, catch rates tended to be higher inshore and in the 0-2.4m depth interval. Strong winds during the field season reduced planned sampling effort resulting in few net days and small sample sizes. The small sample size made analysis and interpretation tenuous.

Experimental Fyke Nets

Experimental fyke nets were fished at six stations, two at Camden Bay and four at Beaufort Lagoon (Figures 2 and 4). Our ability to sample at each station varied. Net station CP10, Camden Bay, was fished for five days. At station CP11 in Camden Bay, the net was fished only one day before being destroyed by rising surf. No fish were captured at CP11 and the effort was not used in any analysis. At Beaufort Lagoon, experimental fyke nets were fished for seven days at BS10, five days at BS11, eleven days at BL12 and five days at BL13.

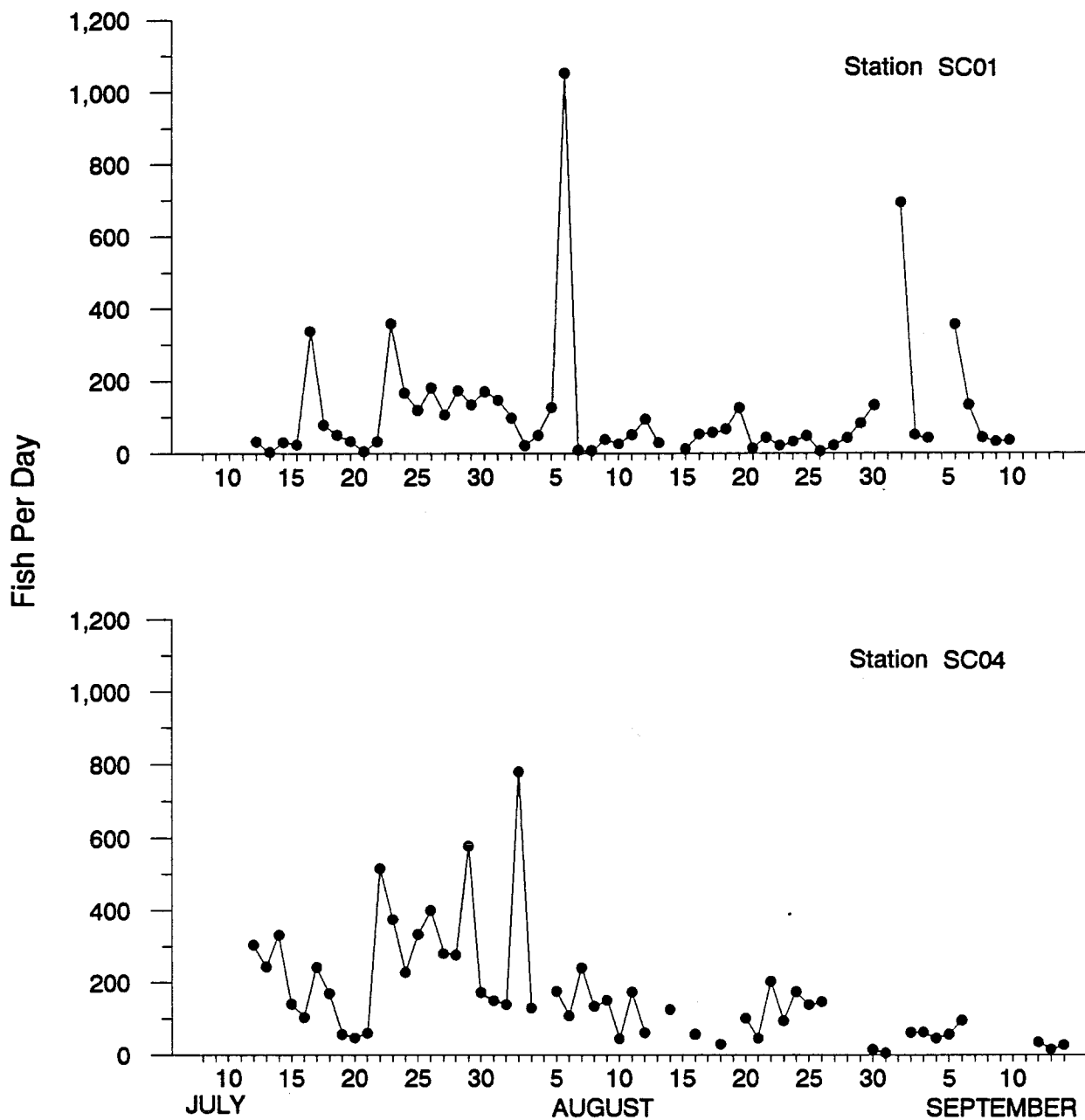


FIGURE 19.— Daily catch per unit effort (fish/d) for fourhorn sculpin at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.

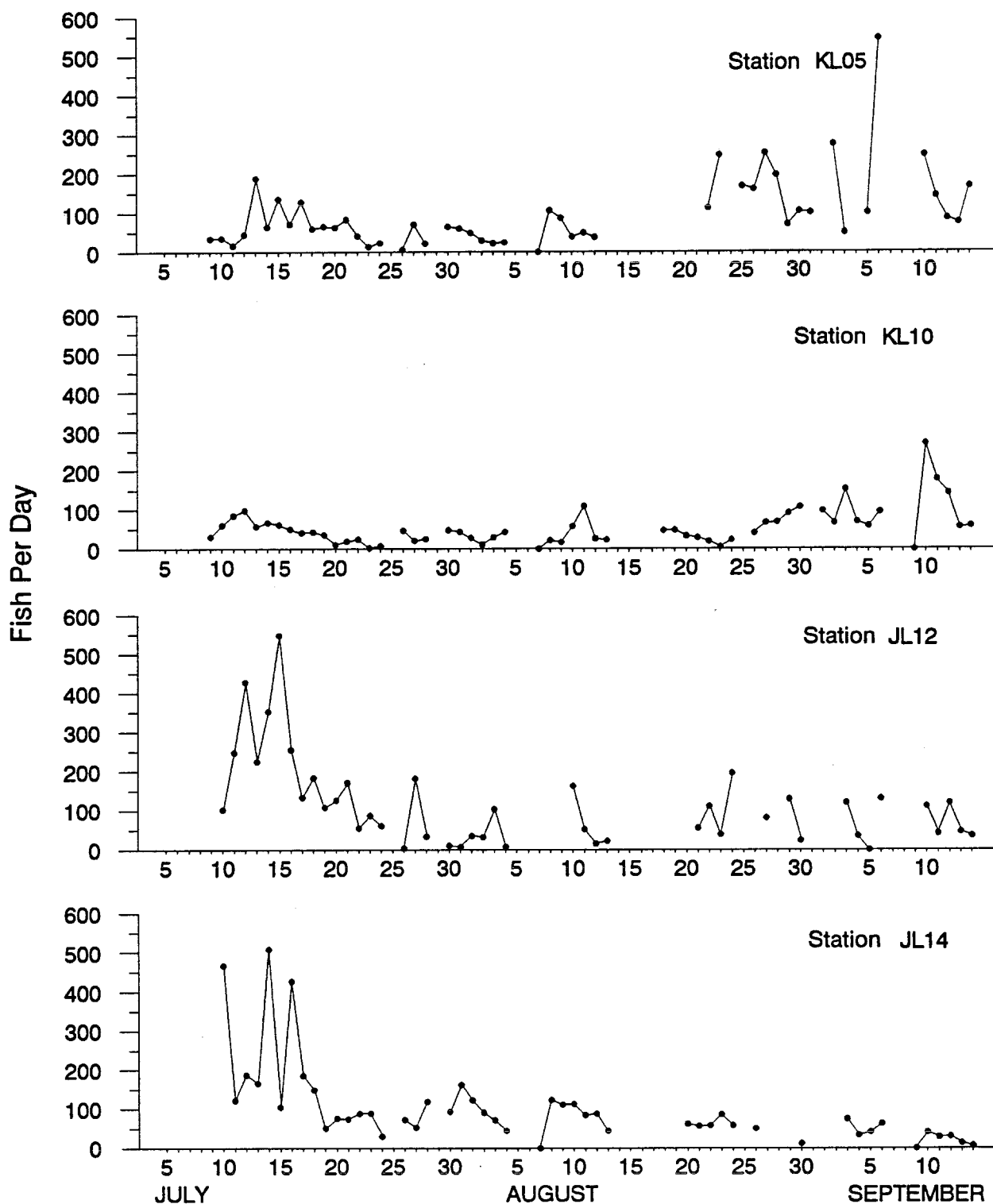


FIGURE 20.— Daily catch per unit effort (fish/d) for fourhorn sculpin at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.

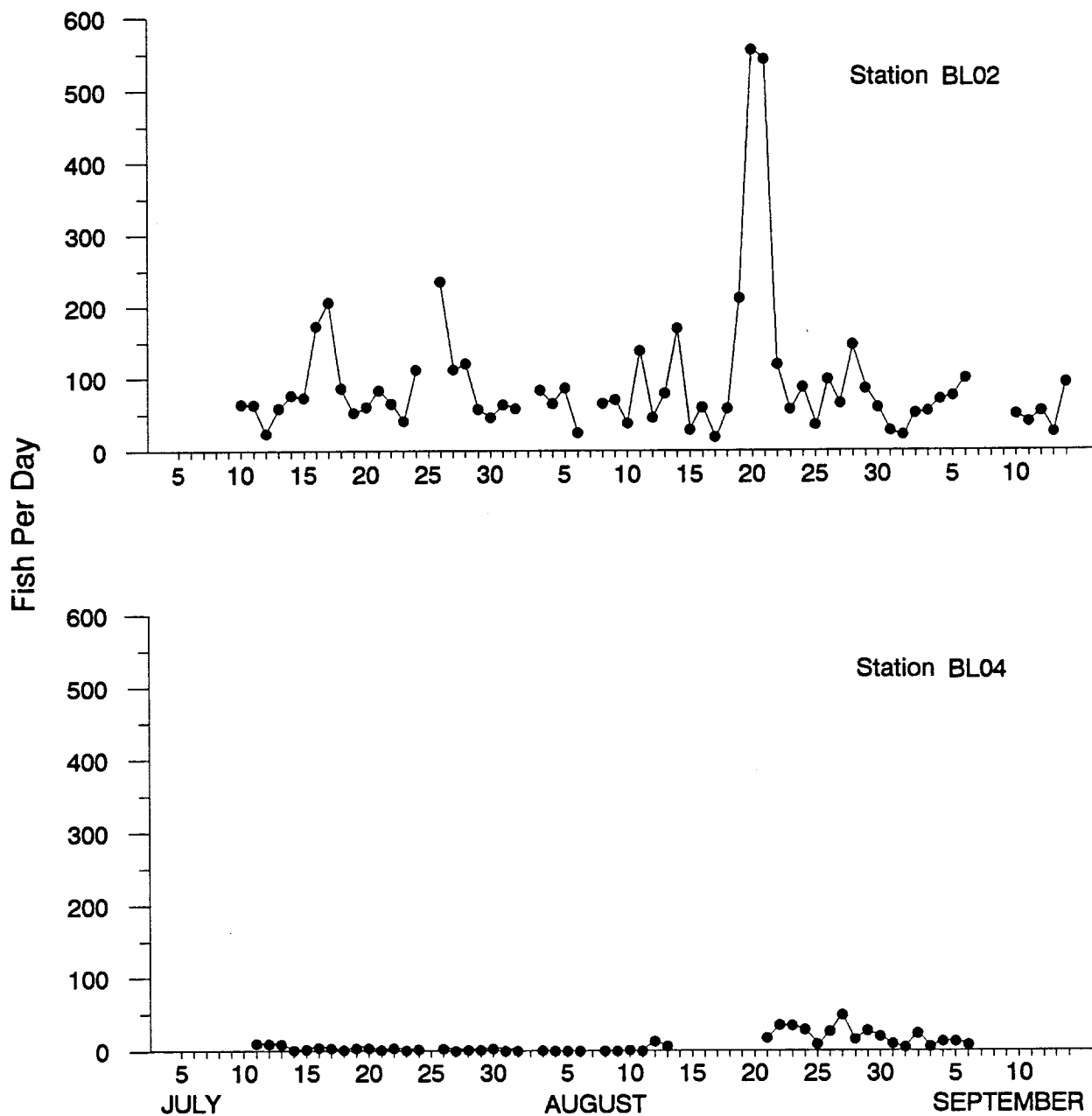


FIGURE 21.— Daily catch per unit effort (fish/d) for fourhorn sculpin at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.

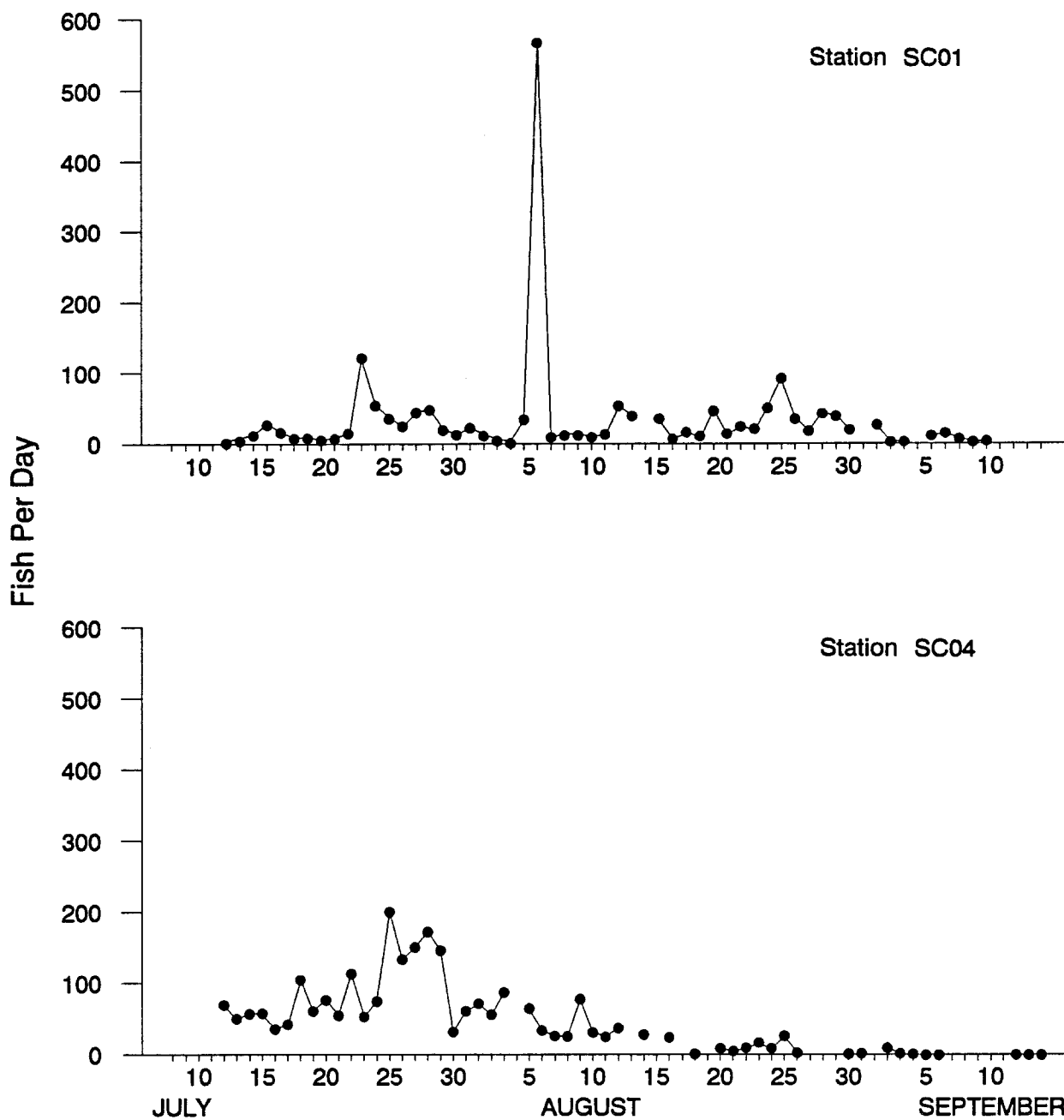


FIGURE 22.- Daily catch per unit effort (fish/d) for Arctic flounder at standard fyke net stations in Camden Bay, Arctic Refuge coastal waters, July-September 1990.

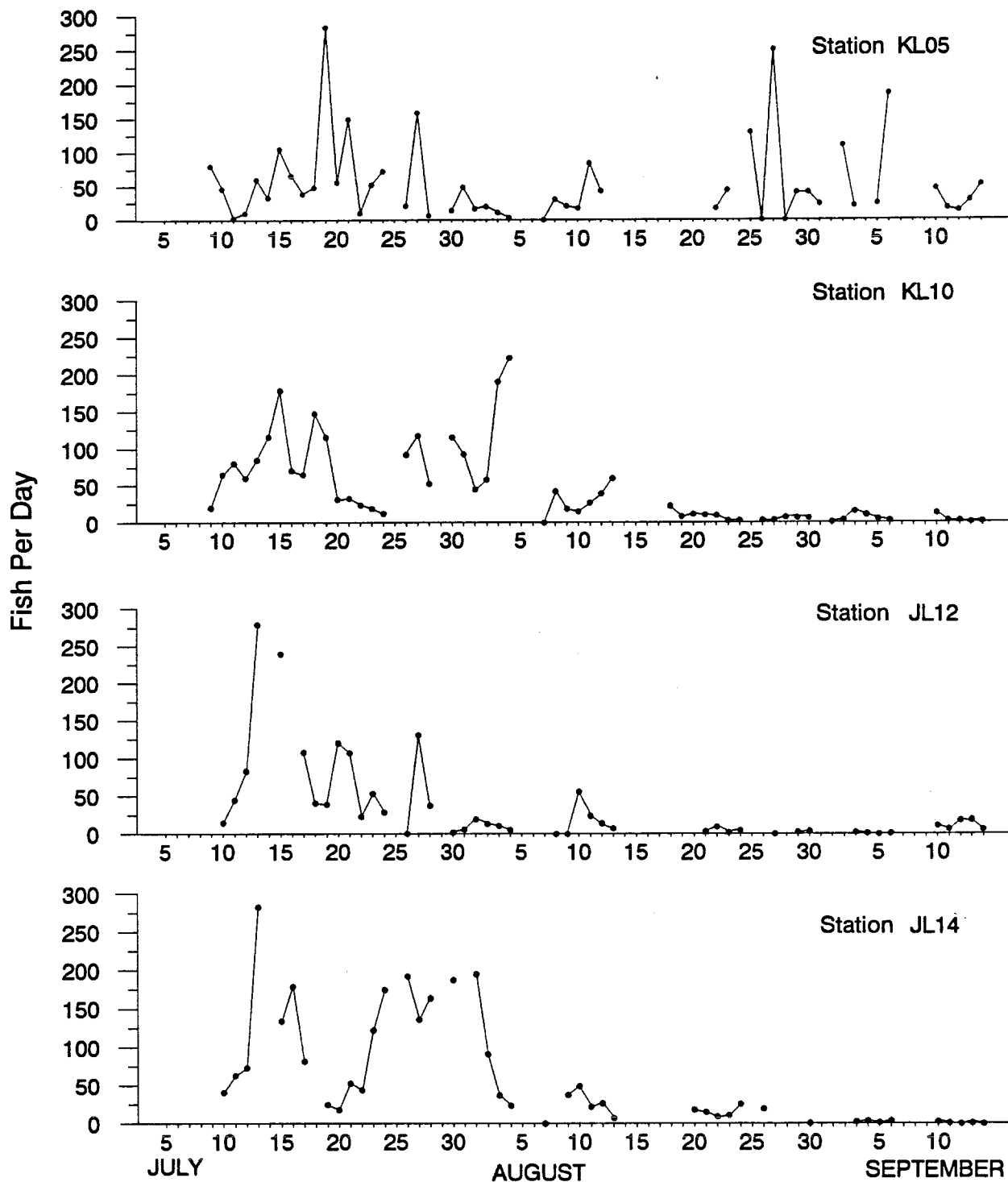


FIGURE 23.— Daily catch per unit effort (fish/d) for Arctic flounder at standard fyke net stations in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.

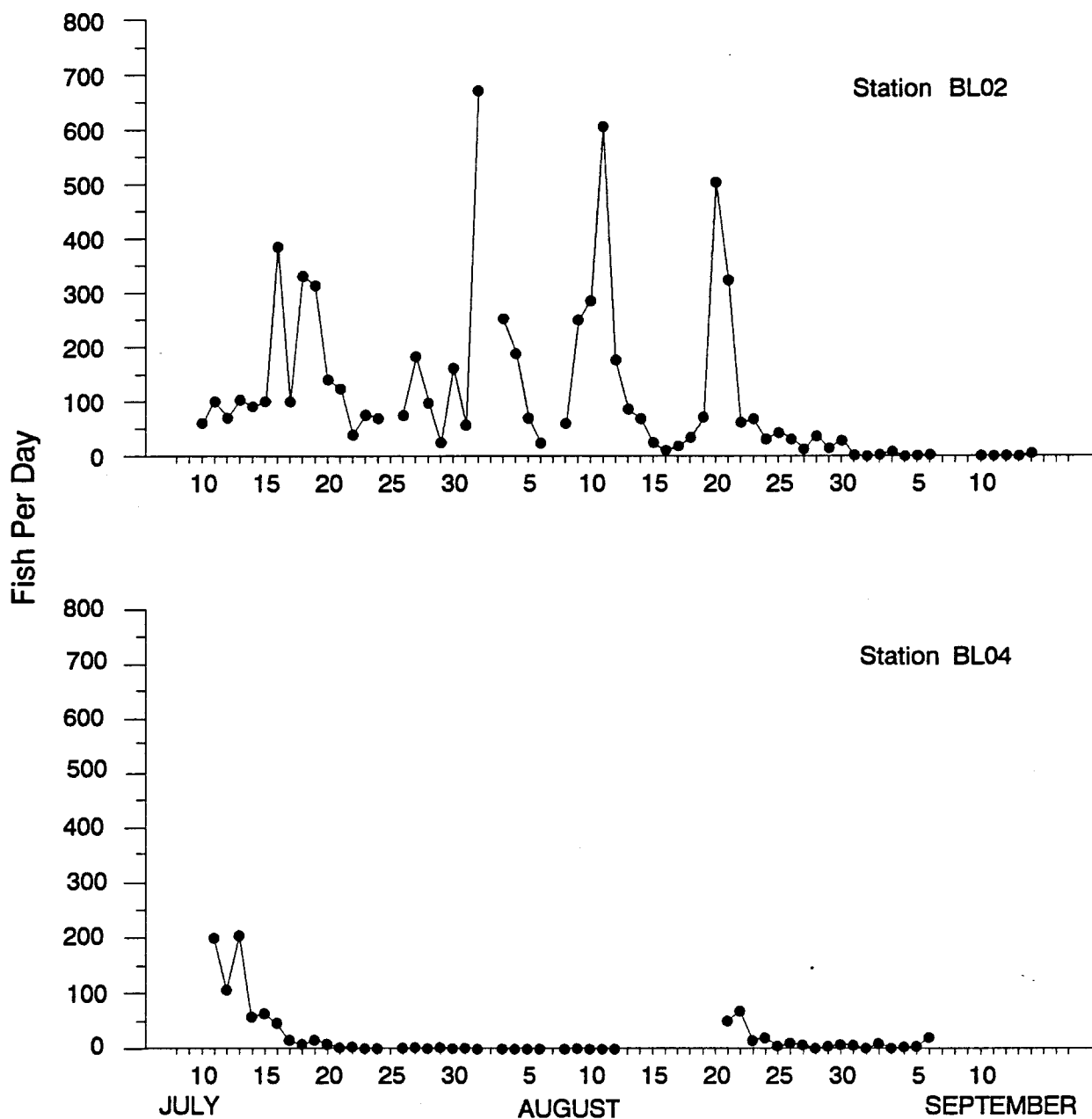


FIGURE 24.- Daily catch per unit effort (fish/d) for Arctic flounder at standard fyke net stations in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.

TABLE 5.— Total catch of Arctic Char and Arctic cisco by gill net sampling stations in Arctic Refuge coastal waters, July - September 1990. CB and CP represent gill net stations off Carter Creek and Collison Point, respectively.

Depth	Stations							
	CB01	CB02	CB04	Total	CP01	CP02	CP04	Total
Arctic char								
0-2.4m	56	27	26	109	36	1	15	52
2.4-4.9m		5	7	12		4	3	7
4.9-7.3m			0	0			1	1
Total	56	32	33	121	36	5	19	60
Arctic cisco								
0-2.4m	19	1	5	25	1	0	0	1
2.4-4.9m		0	0	0		0	0	0
4.9-7.3m			0	0			1	1
Total	19	1	5	25	1	0	1	2

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

TABLE 6.— Mean (\pm SD) catch per hour (CPUE), CPUE range, and number of observations (N) by depth interval for Arctic char caught in gill net sampling in Camden Bay, Alaska, July - September 1990.

Variable	Station			
	CB01	CB02	CB04	CP01 CP02 CP04
0 - 2.4m Depth Interval				
Mean CPUE \pm SD	0.43 \pm 0.57	0.21 \pm 0.28	0.16 \pm 0.43	0.45 \pm 0.51
CPUE Range	0.00 - 1.42	0.00 - 0.80	0.00 - 1.23	0.00 - 0.04
N	8	8	8	5
2.4 - 4.9m Depth Interval				
Mean CPUE \pm SD		0.05 \pm 0.07	0.05 \pm 0.11	0.06 \pm 0.07
CPUE Range		0.00 - 0.17	0.00 - 0.29	0.00 - 0.16
N		8	8	5
4.9 - 7.3m Depth Interval				
Mean CPUE \pm SD			0.00 \pm 0.00	0.02 \pm 0.03
CPUE Range				0.00 - 0.06
N			8	5

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

TABLE 7.- Mean (\pm SD) catch per hour (CPUE), CPUE range, and number of observations (N) by depth interval for Arctic cisco caught in gill net sampling in Camden Bay, Alaska, July - September 1990.

Variable	Station			
	CB01	CB02	CB04	CP01 CP02 CP04
0 - 2.4m Depth Interval				
Mean CPUE \pm SD	0.24 \pm 0.43	0.01 \pm 0.02	0.03 \pm 0.08	0.01 \pm 0.03
CPUE Range	0.00 - 1.29	0.00 - 0.05	0.00 - 0.22	0.00 - 0.06
N	8	8	8	5
2.4 - 4.9m Depth Interval				
Mean CPUE \pm SD		0.00 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00
CPUE Range				
N		8	8	5
4.9 - 7.3m Depth Interval				
Mean CPUE \pm SD			0.00 \pm 0.00	0.01 \pm 0.03
CPUE Range				0.00 - 0.06
N			8	5

Initially, experimental fyke nets were used outside the barrier islands (CP11, BS10, BS11). Difficulty with surf and low catches prompted relocation of nets inside the islands where we collected 99% of the total catch (Table 8). Of the thirteen species captured, small Arctic cisco (≤ 200 mm FL) made up 90% of the catch; fourhorn sculpin 5%; and Arctic flounder 4%. Only three Arctic char and no large Arctic cisco (>200 mm FL) were captured. Only marine species were caught outside the barrier islands with the exception of one Arctic grayling which was found dead in the net. While no small Arctic cisco were caught at outside stations, catch rates for this species ranged from 16 to 201 fish/d at stations inside the barrier islands (Table 9).

LENGTH FREQUENCY DISTRIBUTIONS

Standard Fyke Nets

Arctic char captured in standard fyke nets during the 1990 field season ranged from 86 to 710 mm FL (Figures 25-27, Appendix A). The mode for the pooled data was 250 mm FL. Length frequency distributions varied considerably between areas and time periods. As the season progressed, the number of fish over 400 mm FL decreased. In July, Arctic char from 250 to 350 mm FL were poorly represented in Beaufort Lagoon while they were more abundant in the other sampling areas. In late August, Arctic char from 250 to 300 mm FL dominated the catch in all sampling areas.

Arctic cisco captured during the 1990 field season ranged from 36 to 520 mm FL. Young-of-the-year Arctic cisco (40-90 mm FL) were strongly represented except during July at Camden Bay (Figures 28-30). A second modal group from 110 to 150 mm FL was represented in most distributions. Large Arctic cisco from 350 to 400 mm FL were present from early July through August except at Beaufort Lagoon (Figures 31-33). In Camden Bay, the western most sampling area, fish from 300 to 340 mm FL were well represented in the first and second time period. Moving east, this size group is noticeably reduced in Kaktovik and Jago lagoons and essentially absent at Beaufort lagoon. Larger fish (>350 mm) represented a larger proportion of the catch at the more eastern areas.

Arctic cod ranged in size from 14 to 270 mm FL (Figures 34-36, Appendix A). The mode for the pooled data was 94 mm FL. The size group from 50 to 150 mm FL was distinctive in all length frequency distributions including Beaufort Lagoon where no Arctic cod were captured until September.

Fourhorn sculpin ranged in size from 24 to 298 mm TL (Figures 37-39). Little change in the structure of populations occurred at a given area between time periods. Typically, two or more modal groups were present in each time period. Modal groups were not widely separated, but often occurred at 60 to 100 mm TL and 110 to 140 mm TL.

Arctic flounder captured during the 1990 field season ranged in size from 26 to 350 mm TL (Figures 40-42).

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

TABLE 8.- Total experimental fyke net catch by sampling stations in Arctic Refuge coastal waters, July-September 1990.

Species	Camden Bay		Beaufort Lagoon				Total
	CP10	BL12	BL13	BS10	BS11		
Arctic cod	12	3	1	0	0	16	
Fourhorn sculpin	82	178	234	16	1	511	
Ninespine stickleback	3	18	2	0	0	23	
Arctic flounder	2	337	79	0	3	421	
Arctic cisco (≤200 mm FL)	807	7,605	419	0	0	8,831	
Arctic cisco (>200 mm FL)	0	0	0	0	0	0	
Arctic char	3	0	0	0	0	3	
Saffron cod	0	6	0	1	0	7	
Rainbow smelt	2	2	1	0	0	5	
Slender eelblenny	0	0	0	0	0	0	
Arctic sculpin	2	2	1	0	1	6	
Broad whitefish	0	0	0	0	0	0	
Least cisco	3	0	1	0	0	4	
Pacific herring	0	0	0	0	0	0	
Pink salmon	0	0	0	0	0	0	
Capelin	5	1	0	0	0	6	
Arctic grayling	0	0	0	0	1	1	
Arctic hookear sculpin	0	0	0	0	0	0	
Arctic staghorn sculpin	0	0	0	0	0	0	
Round whitefish	0	0	0	0	0	0	
Greenland seasnail	3	0	0	0	0	3	
Pacific sand lance	0	0	0	0	0	0	
Bering wolffish	0	0	0	0	0	0	
Unidentified sculpin	0	0	0	0	0	0	
Unidentified smelt	0	0	0	0	0	0	
Total	924	8,152	738	17	6	9,837	

ARCTIC NATIONAL WILDLIFE REFUGE COASTAL FISH STUDY, 1990

TABLE 9.- Seasonal catch per unit effort (fish/d) by experimental fyke net sampling stations in Arctic Refuge coastal waters, July - September 1990.

Species	Camden Bay		Beaufort Lagoon				Area
	CP10	BL12	BL13	BS10	BS11		
Arctic cod	0.4	<0.1	<0.1	0	0	<0.1	
Fourhorn sculpin	3.0	4.7	8.7	2.7	0.2	5.6	
Ninespine stickleback	0.1	0.5	<0.1	0	0	0.3	
Arctic flounder	<0.1	8.9	2.9	0	0.5	5.5	
Arctic cisco (≤200 mm FL)	29.8	201.4	15.6	0	0	105.0	
Arctic cisco (>200 mm FL)	0	0	0	0	0	0	
Arctic char	0.1	0	0	0	0	0	
Saffron cod	0	0.2	0	0.2	0	0.1	
Rainbow smelt	<0.1	<0.1	<0.1	0	0	<0.1	
Slender eelblenny	0	0	0	0	0	0	
Arctic sculpin	<0.1	<0.1	<0.1	0	0.2	<0.1	
Broad whitefish	0	0	0	0	0	0	
Least cisco	0.1	0	<0.1	0	0	<0.1	
Pacific herring	0	0	0	0	0	0	
Pink salmon	0	0	0	0	0	0	
Capelin	0.2	<0.1	0	0	0	<0.1	
Arctic grayling	0	0	0	0	0.2	<0.1	
Arctic hooker sculpin	0	0	0	0	0	0	
Arctic staghorn sculpin	0	0	0	0	0	0	
Round whitefish	0	0	0	0	0	0	
Greenland seasnail	0.1	0	0	0	0	0	
Pacific sand lance	0	0	0	0	0	0	
Bering wolffish	0	0	0	0	0	0	
Unidentified sculpin	0	0	0	0	0	0	
Unidentified smelt	0	0	0	0	0	0	

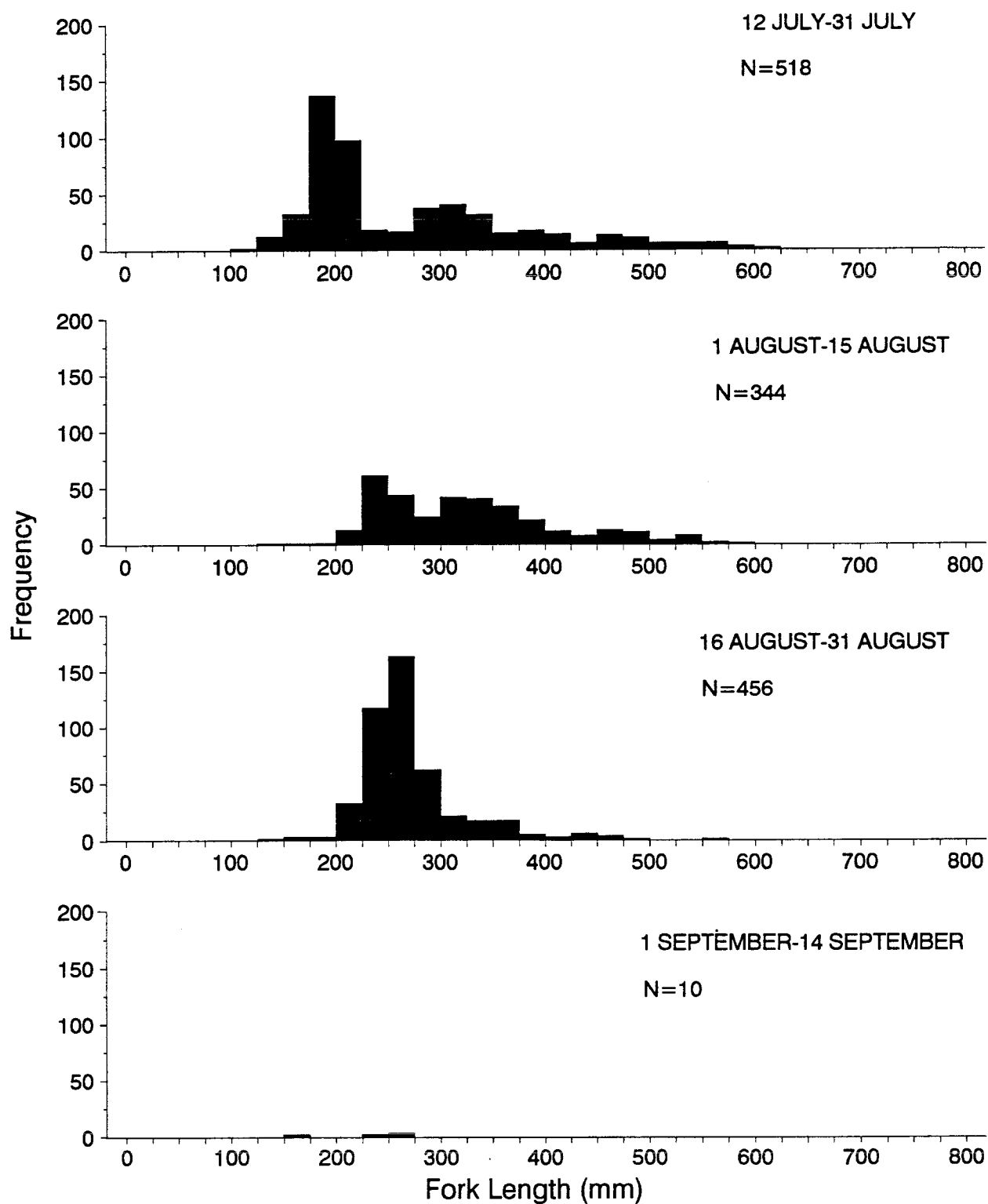


FIGURE 25.- Length frequency of Arctic char captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.

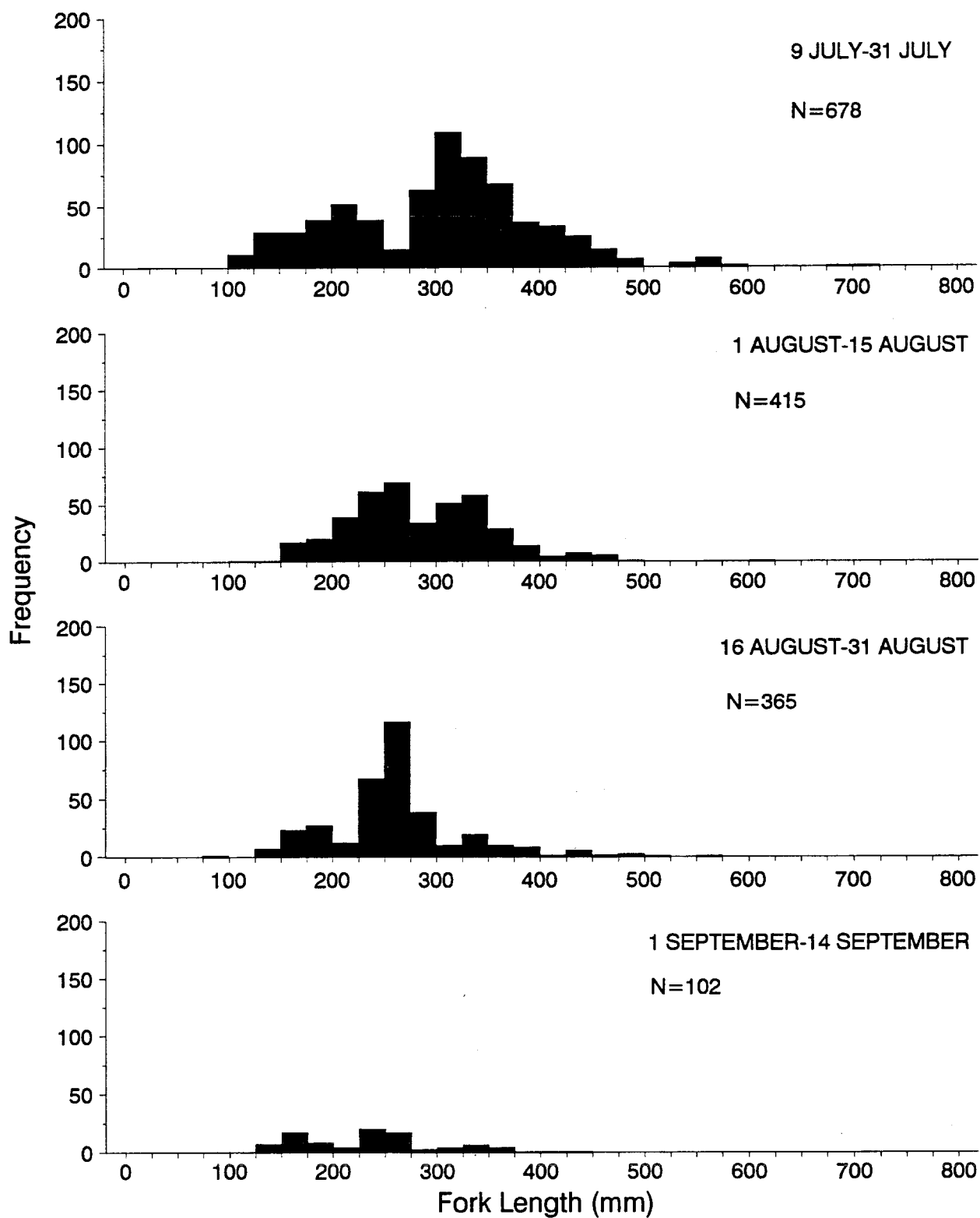


FIGURE 26.— Length frequency of Arctic char captured by fyke nets in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.

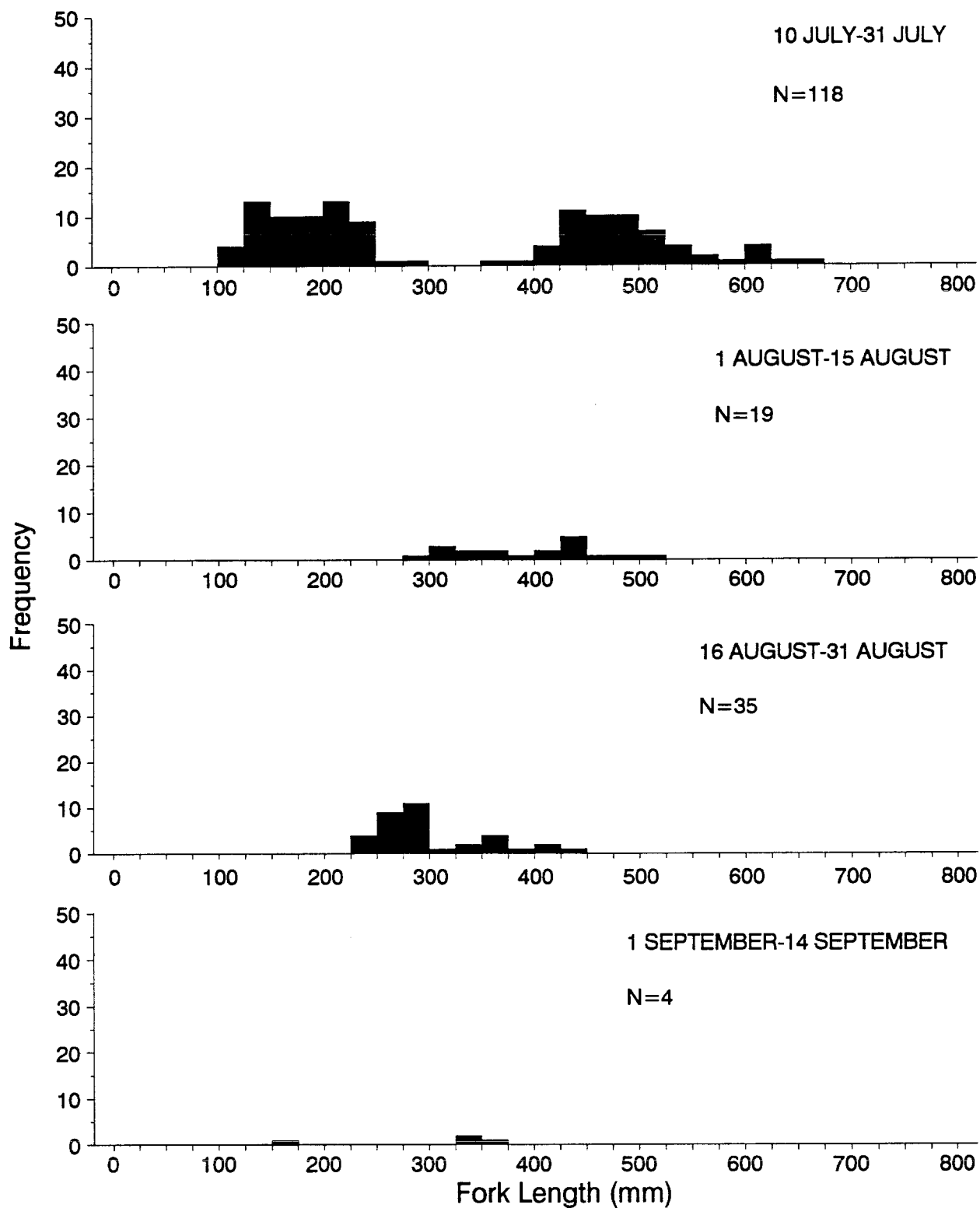


FIGURE 27.- Length frequency of Arctic char captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.

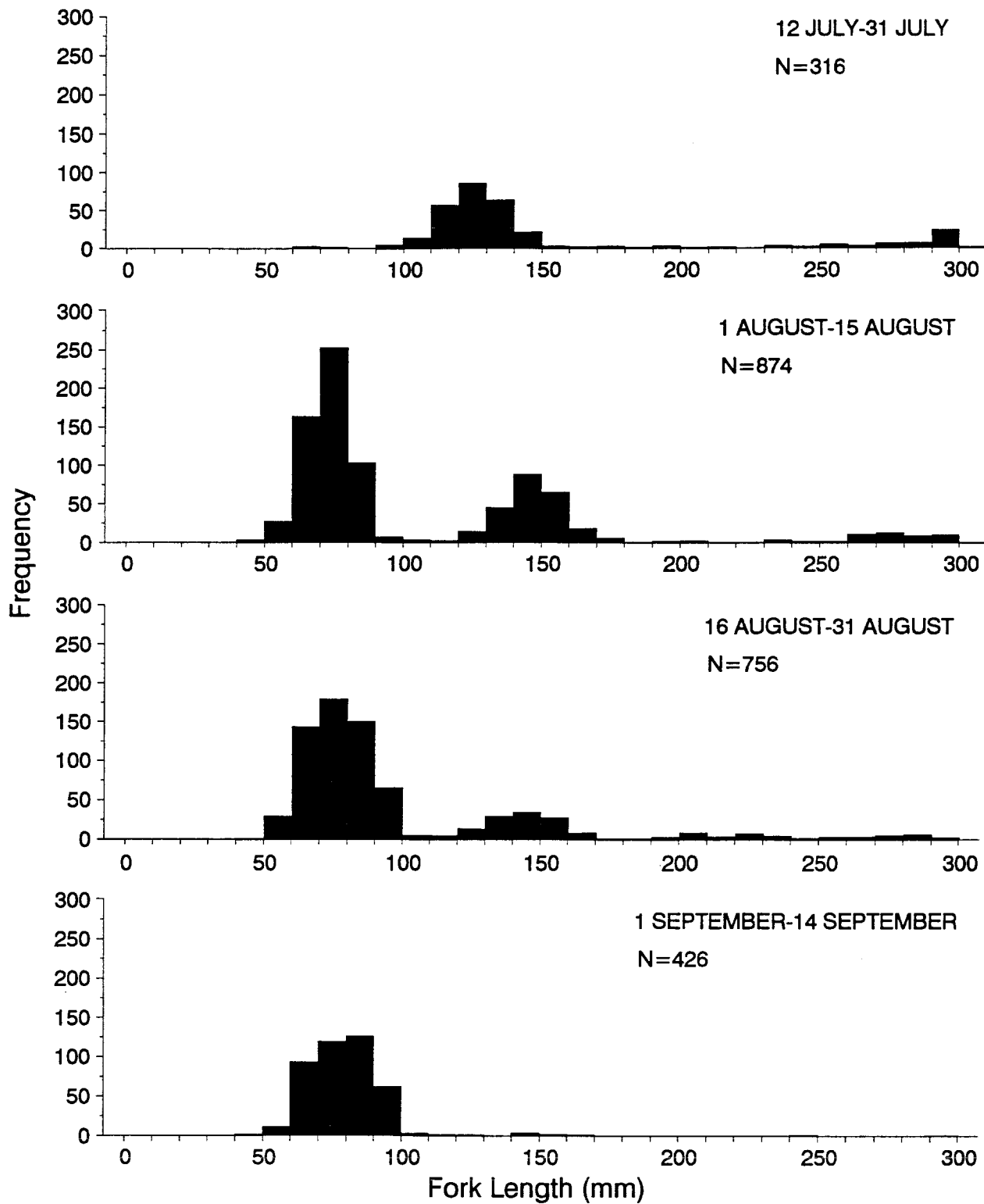


FIGURE 28.— Length frequency of small Arctic cisco (<300 mm FL) captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1990.

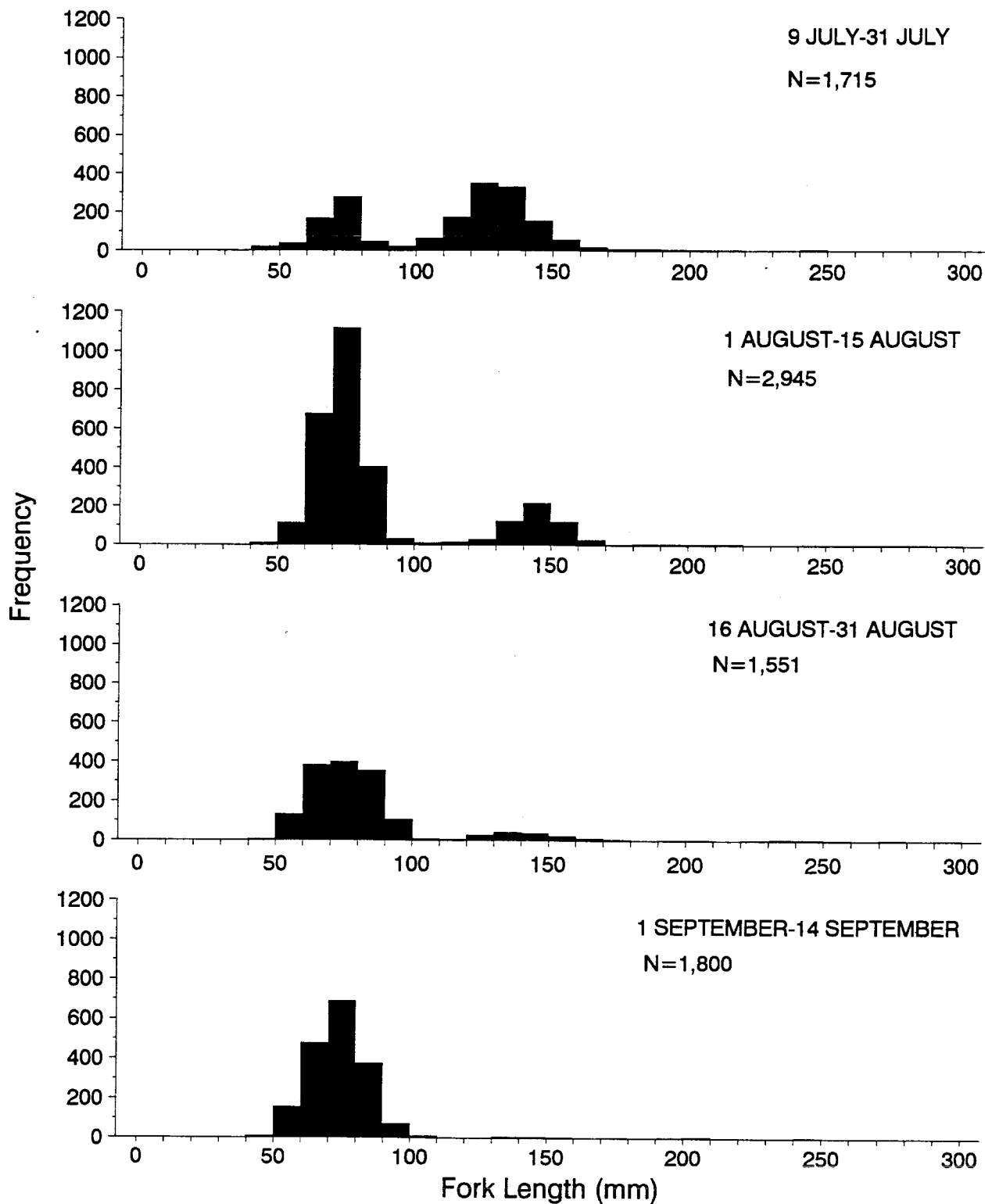


FIGURE 29.— Length frequency of small Arctic cisco (<300 mm FL) captured by fyke nets in Kaktovik and Jago lagoons, Arctic Refuge coastal waters, July-September 1990.

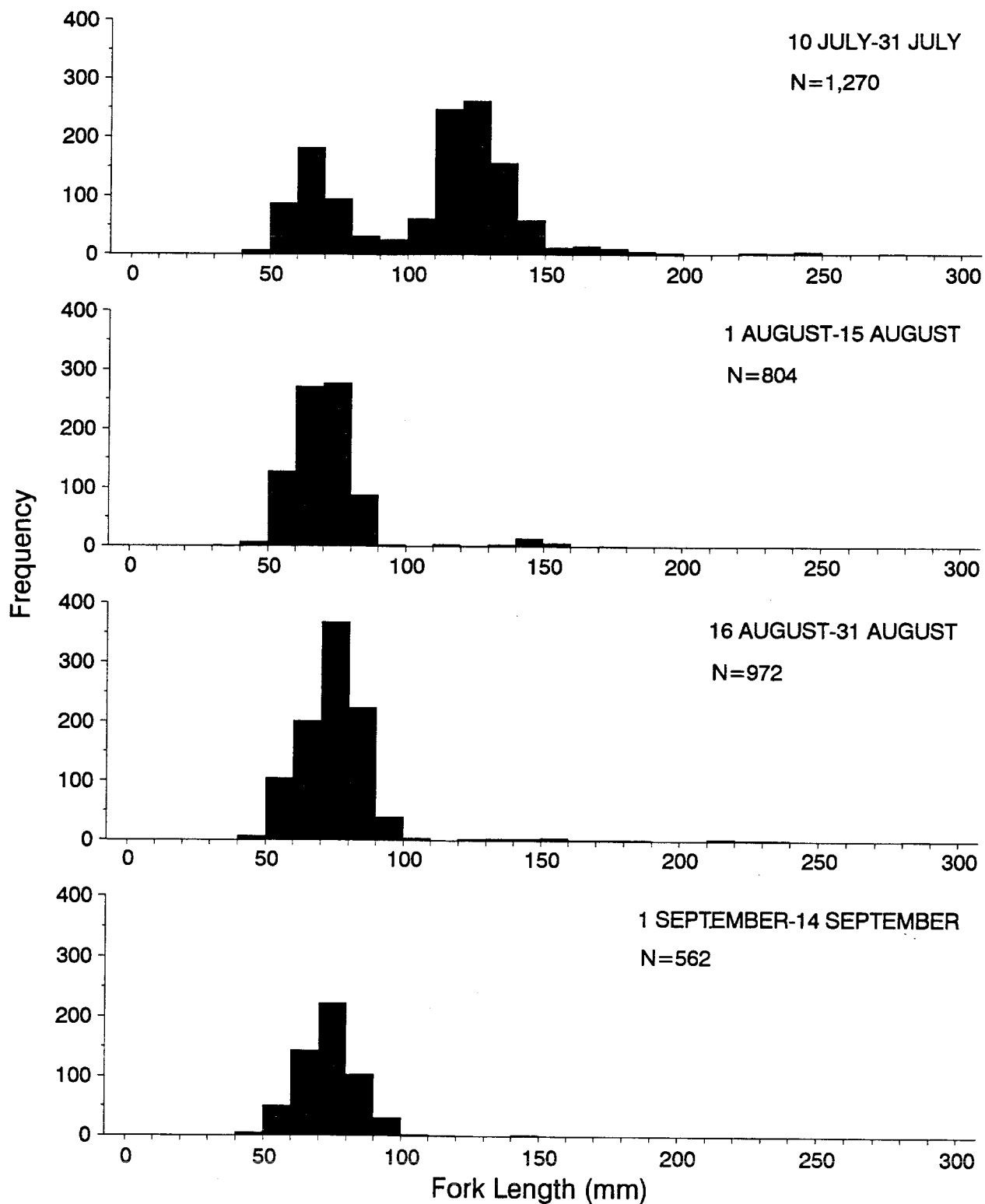


FIGURE 30.- Length frequency of small Arctic cisco (<300 mm FL) captured in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1990.